CHAPTER 12

IMPERMEABLE COVER

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CHAPTER 12

IMPERMEABLE COVER

12.1 REMEDIAL DESIGN REQUIREMENTS

12.1.1 Consent Decree Requirements

The Remedial Design Action Plan (RDAP) included in the Consent Decree states the following (p.7):

> "The remedial action for control of air emissions is intended to mitigate the release or threat of release of Hazardous Substances, including odors associated with decaying hide waste, in the East Hide Pile."
>
> "The remedial action shall consist of stabilizing the side slopes of the East Hide Pile, installing a gas collection layer, capping with a synthetic membrane to establish impermeability, and soil cover in accordance with [RDAP] Attachment A...."

Attachment A to the RDAP states that:

> "Impermeable covers shall be designed and constructed to include at a minimum the following:
>
> (a) A vegetated top layer which shall be,
>
> (1) of a thickness designed to accommodate the maximum depth of root penetration and the rate of anticipated soil loss, but in any event no less than 6 inches;
>
> (2) capable of supporting vegetation that minimizes erosion and minimizes continued maintenance;
>
> (3) planted with a persistent species with roots that will not penetrate beyond the vegetative and drainage layers;
>
> (4) designed and constructed with a top slope of between 3 percent and 5 percent after settling and subsidence or, if designed and constructed with a slope of greater than 5 percent, an expected soil loss of less than 2 tons/acre/year using the USDA universal soil loss equation; and

(5) designed and constructed with a surface drainage system capable of conducting effective run-off across the cap.

(b) A middle drainage layer that shall be:

(1) of a thickness designed to accommodate the expected amount of settling and the maximum volume of water that could enter the drainage layer, but in any event no less than 6 inches;

(2) consisting of a material whose permeability exceeds $1x10^{-3}$ cm/sec., i.e. a sand in the SW or SP range of the Unified Soil Classification System or coarser material.

(3) designed and constructed with a bottom slope of at least 2 percent; and

(4) designed and constructed to prevent clogging.

(c) A bottom impermeable layer consisting of the following:

(1) an impermeable synthetic membrane having a thickness of at least 40 mils;

(2) a bedding layer designed to prevent clogging of the underlying gas collection layer and to provide a stable base for overlying layers (The gas collection layer may itself serve as the bedding layer provided that it will support the weight of the cap and will not abrade the synthetic membrane.);

(3) a final upper slope of at least 2 percent

The thickness of the vegetated top layer and drainage layer combined shall be designed so that the impermeable layer is wholly located below the average depth of frost penetration in the area of interest, unless the Settlers can demonstrate during remedial design that a reduction in thickness of the overlying layers will not affect the integrity of the synthetic membrane."

A discussion of the functions and requirements of the impermeable cover was presented in Section 2.3 of the Pre-Design Investigation (PDI) Task S-3 Interim Final Report (Golder, 1990a). This section is included in Appendix 12-A as a reference.

12.1.2 Remedial Design Work Plan Requirements

The Remedial Design Work Plan (RDWP; Golder, 1990b) establishes that the 100% Design Report is to include the following impermeable cover design elements:

1. Final design of slopes;
2. Cover section;
3. Stabilization mechanism, location, and sections;
4. Definition of cap extent;
5. Grading plan; and,
6. Gas vent spacing.

12.2 DESIGN SUMMARY

The design process for the impermeable cover on the East Hide Pile followed a specific logic. The results from this process lead to an alternative to the cover design specified in the Record of Decision (ROD) and Consent Decree. The logic and conclusions drawn at each stage of the design process are summarized herein. The stages of the design process were as follows:

a) Stability analysis of the East Hide Pile under existing conditions;

b) Establishment of a preliminary grading plan for the East Hide Pile cover, followed by the stability analysis for the as-graded configuration;

c) Analysis of ROD Cover Stability;

d) Identification of ROD Cover Stabilization Methods; and,

e) Identification of an Alternative Cover.

The stability analysis of the East Hide Pile in its current configuration was conducted for several cross-sections where the slope geometry and soil conditions are critical. It was concluded that the pile is stable under present conditions, except for the surface sloughing mode which can be ameliorated by placement of the cover. The slope stability analyses for the existing conditions is discussed in detail in Section 12.3.1.1.

The grading plan initially designed for the East Hide Pile utilized a minimum slope of 5 percent and maximum slope of 33 percent. The stability analysis for the as-graded condition showed that the East Hide Pile would be stable for that grading configuration. The slope stability analyses for the regraded configurations is discussed in detail in Section 12.3.1.2.

The stability of the ROD specified cover on the East Hide Pile was then assessed for the proposed grading plan. The stability of the cover section is controlled by the friction on the weakest interface. For the ROD impermeable cover cross-section, the weakest interface is between the middle drainage sand layer and the geomembrane, with typical interface friction angles between 17 to 19 degrees. The conclusion reached was that the ROD specified cover would not be stable in this configuration.

The next step in the design process consisted of evaluating methods to stabilize the ROD specified cover. Two alternatives were identified. The first consisted of placing the cover at a uniform 20 percent slope, which corresponds to a factor of safety of 1.5 for the critical interface friction angle. This approach, while being stable, would have required a significant amount of fill which would have encroached well into Wetland 1C. The second alternative consisted of placement of the cover at a 20 percent slope with construction of a retaining wall at the edge of Wetland 1C. The retaining wall would have been a massive structure on the order of 1,000 feet long, having a height of nearly 22 feet, whose construction would have caused significant impact to the wetlands. A structure of this size would also require considerable maintenance, present a safety hazard and have a negative visual impact. In addition, the structure would be a barrier to wildlife.

To minimize wetlands disturbance and avoid the problems associated with grading the East Hide Pile with flatter slopes, the next step in the design process consisted of identifying an alternative impermeable cover design. This alternative impermeable cover system includes a gas collection system which consists of 6 inch diameter fiberglass piping wrapped in geotextile and embedded in 12 inches of open-graded medium gravel (AASHTO No. 8). The gas collection system is discussed further in Chapter 15. A 10 ounce/square yard nonwoven geotextile separates the gravel from an overlying geomembrane. The geomembrane comprises textured 60-mil high-density polyethylene (HDPE) and is in turn overlain by a geocomposite drainage layer. The geocomposite drainage layer consists of a geonet with a geotextile factory heat bonded on both sides (Tex-Net TN3002CN, or equivalent). An 18 inch cover soil layer overlies the geocomposite and consists, from bottom to top, of 14 inches of select fill and 4 inches of topsoil. The surface will be vegetated.

Stability analyses confirmed that this alternative cover is stable at slopes of 33 percent. The stability analyses for the alternate cover is presented in detail in Section 12.3.1.3.

12.3 DESIGN CONSIDERATIONS

12.3.1 Slope Stability

Slope stability analyses were conducted on the East Hide Pile for existing and remediated conditions. Four cross-sections were analyzed for existing conditions. Sections E-E′ and F-F′ represent areas where the geometry is most critical, while Sections P-P′ and V-V′ drawn through Boreholes 9 and 11, respectively, represent areas where additionally weaker soils were encountered. Remediated conditions were analyzed for Sections F-F′, P-P′ and V-V′ which were found to have the lowest factors of safety for existing conditions. The locations of these cross-sections are identified on Figure 12-1. The results of the slope stability analyses are presented in Appendix 12-B for existing conditions and in Appendix 12-C for remediated conditions.

Two series of slope stability analyses were conducted both for existing and remediated conditions: one representing the long-term groundwater condition without a perched water table and the other including the effect of a possible perched water table. Groundwater levels were based upon borehole observations as presented in the PDI Task S-2 Interim Final Report (Golder, 1990c).

Because the materials that form the hide pile were found to behave as cohesionless soils, the critical failure mechanism was generally shallow surface sloughing with semi-planar failure surfaces parallel to the slope where the surficial soils are locally weaker or where water tables are present. The analysis of planar failure surfaces in cohesionless soils is most appropriately conducted using the infinite slope theory (Lambe & Whitman, 1969). In order to model possible deeper seated failure mechanisms for the long-term groundwater condition, analysis was carried out using the PCSTABL5M version of the computer program STABL developed by Purdue University (Purdue University, 1988). Circular failure surfaces were analyzed using the simplified Bishop method, applying restrictions to the failure initiation and termination zones to preclude the shallow surface sloughing mode, which was analyzed separately as described above. The PCSTABL5M program permits analysis of large numbers of potential circular failure surfaces per run and automatically searches for the most critical; in this case 400 surfaces per run were analyzed. The slope stability results are summarized on Table 12-1.

The cross-sections analyzed for the individual slope stability runs are illustrated in Appendices 12-B and 12-C. The soil parameters used for the analyses were those recommended in the PDI Task S-2 Interim Final Report (Golder, 1990c) as described below.

A unit weight (saturated) of 100 pcf and an effective angle of shearing resistance of 25 degrees with zero cohesion was used for the Surficial Material.

Unit weights determined from undisturbed Shelby tube samples of Fill and Hide Residue prior to extrusion indicated a range of values of 65 to 130 pcf, reflecting variations in the local degree of compaction and the degree of saturation associated with perched water tables. A conservative value of 125 pcf was selected for slope stability calculations.

Shear strength parameters for the Fill and Hide Residue were assessed from the results of triaxial tests and SPT 'N' values. For heterogeneous materials of this nature, the most reliable triaxial strength parameters were obtained by considering all of the test results together to define a single failure envelope that accounts for the volumetric changes associated with the development of shearing ("steady state" shear strength) rather than by assessing distinct values for each test from the Mohr circles. A large number of results were conveniently assessed in this way by plotting the failure points on a p'-q plot, where:

$$p' = \frac{\sigma 1' + \sigma 3'}{2} \qquad q = \frac{\sigma 1' - \sigma 3'}{2}$$

$\sigma 1'$ and $\sigma 3'$ being the major and minor principal effective stresses at failure. The conventional Mohr-Coulomb failure parameters c' and σ' are related to the slope (ψ) and intercept (d) of the p'-q plot as follows:

$$\sin \phi' = \tan \psi$$

$$c' = \frac{d}{\cos \phi'}$$

A p'-q plot for the Fill and Hide Residue is presented in Appendix 12-B. The data is reasonably consistent, both between consolidated undrained tests with pore pressure measurement and consolidated drained tests, for both undisturbed samples and specimens remolded at field water content and density. A "best fit" line through the data gave an effective angle of friction of 37 degrees and an effective cohesion of 2 psi. A lower bound line corresponds to an effective angle of friction of 34 degrees and zero effective cohesion.

The SPT results for Fill and Hide Residue are plotted against depth in Appendix 12-B. The data showed a range of values, as would be expected for a heterogeneous material of this nature, with a clear trend of increasing 'N' value with depth. Using the work of Schmertmann (1975) to account for overburden effects and noting low 'N' values which are likely to have been affected by piping, suggested an effective angle of shearing resistance of 35 degrees.

It was considered unwise to rely on a cohesive strength component for such a heterogeneous material and a prudent allowance was also made for possible future degradation of material properties as a result of continuing anaerobic decomposition of the hide materials. Considering this and the above discussions, effective shear strength parameters of zero cohesion and 34 degrees friction angle were selected for the Fill and Hide Residue.

In the specific cases of Boreholes 9 and 11, it was recognized that the SPT 'N' values indicate possibly lower shear strengths of the Fill and Hide Residue locally; these boreholes are not, however, located at the geometrically critical sections of the East Hide Pile from a stability point of view. Based on the work of Schmertmann (1975), lower bound effective angles of shearing resistance of 31 degrees and 28 degrees were interpreted for the Fill and Hide Residue in Boreholes 9 and 11, respectively, as detailed in Appendix 12-B.

A unit weight (saturated) of 120 pcf and an effective angle of shearing resistance of 36 degrees with zero cohesion were selected for the Outwash Sand. A unit weight (saturated) of 125 pcf and an effective angle of shearing resistance of 37 degrees with zero cohesion were selected for the Glacial Till.

12.3.1.1 Existing Conditions

The case of shallow surface sloughing was analyzed for the existing conditions using the infinite slope model and the average slope of Section F-F′ equal to 26 degrees. A factor of safety of 1.0 was obtained for the long-term groundwater condition. For perched water table conditions, analyses were performed for seepage emerging from and parallel to the slope; factors of safety of 0.2 and 0.5 were obtained, respectively, confirming the controlling influence of perched water tables on the current stability.

Circular analyses were conducted for the long-term groundwater condition for Sections E-E′, F-F′, P-P′ and V-V′. Factors of safety of 2.1, 1.9, 1.5, and 1.8 were obtained, respectively, indicating that Section F-F′, P-P′ and V-V′ are the most critical, and confirming that, as anticipated, deeper failure surfaces are less critical than surface sloughing for this type of material. Circular analyses were also conducted for Section F-F′ adopting a conservative perched water table, affecting the upper half of the slope with a phreatic surface at approximately 75 percent of the slope height. A factor of safety of 1.9 was calculated, comparable to that of the long-term groundwater case.

For the type of profile determined for the East Hide Pile, in which no weaker layers have been detected interlayered with other soils, circular surfaces are expected to be more critical than non-circular surfaces. However, as a verification, a limited number of feasible non-circular potential failure surfaces were also analyzed for the long-term groundwater condition on Section F-F′, using PCSTABL5M with the Spencer method. These yield a minimum factor of safety of 2.0.

The computer data for each PCSTABL5M run are included in Appendix 12-B with cross-sections showing the critical failure surfaces.

12.3.1.2 Remediated Conditions

Slope stability analysis were conducted on remediated conditions for the most critical sections determined for existing conditions, that is, Sections F-F′, P-P′ and V-V′. Perched water table conditions were not analyzed since the construction of an impermeable cover will prevent the development of perched conditions.

As discussed above, the critical failure mechanism prior to remediation is shallow surface sloughing associated with cohesionless, Surficial Materials. This failure mechanism is precluded with the proposed remediated plan, since compacted granular fill will be placed to flatten the slopes. Proof rolling of the Surficial Material on the existing slope surface will be undertaken prior to placement of the fill in areas where the existing slope is 2.5H:1V or flatter, which can be achieved by drum and rear wheel drive rollers. The surface of existing slopes steeper than 2.5H:1V can not be proof rolled; however, the thickness of compacted fill in front of these slopes will be significant and will be sufficient to prevent sloughing.

The cross-section geometries analyzed for these remediated condition are illustrated with their individual slope stability run outputs in Appendix 12-C. Additional materials used in the remediated condition analyses, or any modifications made to the soil parameters previously used in the existing condition analyses, are discussed below.

The conservative assumption that the cover materials provide weight only (unit weight 120 pcf) and have zero shear strength was made.

Select fill material to be used for grading purposes beneath the cover was analyzed with a unit weight of 125 pcf and an effective angle of shearing resistance of 33 degrees with zero cohesion. Materials chosen for this fill will have to meet these standards as required in the construction specifications.

Sections F-F', P-P' and V-V' were analyzed for the long-term groundwater condition, with alternate unit weights of 125 and 115 pcf for the Fill and Hide Residue, to reflect the variability of this material.

The factors of safety obtained in these analyses were 2.3, 2.2 and 2.8 for Sections F-F', P-P' and V-V', respectively.

The analysis of the slope stability of the East Hide Pile in the remediated condition concludes that the proposed grading plan is acceptable. The computer output data from the PCSTABL5M runs and cross-sections showing the critical failure surfaces for the remediation conditions are included in Appendix 12-C.

12.3.1.3 Cover Interface Friction

A testing program using representative soils and geosynthetic samples was undertaken to verify the interface friction angle selected for the design. A detailed discussion of the laboratory testing program conducted to evaluate the interface friction angle between the cover soil and the different geosynthetics used in the hide piles covers is presented in Appendix 11-E. The results of this program indicate that the minimum residual interface friction angle between a soil cover of the type that has been specified for the East Hide Pile and the geotextile or geocomposite, or between the geocomposite and the textured HDPE, is 30 degrees.

The grading plan for the East Hide Pile cover has been designed in such a way that the slopes do not exceed 33 percent (18.3 degrees). For slopes of 18.3 degrees or less, under the assumption of infinite slope, the calculated factor of safety with respect to sliding of the cover is 1.7 for the minimum friction angle of 30 degrees.

Additional interface friction testing shall be performed using the actual borrow sources for cover material and geosynthetics prior to construction, as outlined in the specifications.

12.3.2 Soil Erosion

Calculations of soil loss based on the USDA Universal Soil Loss Equation as presented in the USEPA document entitled "Evaluating Cover Systems for Solid and Hazardous Waste" (Lutton, 1982, Revised Edition) are included in Appendix 12-D. These calculations show an expected soil loss of 1.66 tons per acre per year, below the specified 2 tons per acre per year. Establishing vegetative cover as quickly after construction as possible should further aid in the prevention of soil loss.

12.3.3 Frost Penetration

The Alternate Cover Design Report (Golder, 1989) concluded that the depth of frost penetration for an average winter at the Site would be contained within a cover thickness of 16 inches. The cover soil on the East Hide Pile has a design thickness of 18 inches. Thus, frost prevention in an average winter will be contained within the cover soil. The geocomposite drain will serve to prevent the formation of water films during thawing.

12.3.4 Settlement

The allowable settlement for which a structure has to be designed depends on its specific characteristics and function. The impermeable cover to be constructed on the East Hide Pile is not a structure sensitive to settlements, because it is very flexible and will not support other structures. Therefore the assessment of the effects of settlements included in this section considers strains that could occur in the cover and the maintenance of appropriate drainage.

Calculations of the maximum differential settlement of the cap as a consequence of variations in the thickness of the hide pile are presented in Appendix 12-E. These calculations are based on one-dimensional compressibility which is appropriate for the present case of a wide, flexible loaded area. Additional calculations are presented in Appendix 12-E of the maximum differential settlement of the cap as a consequence of the heterogeneity in the properties of the soils. These calculations were based on Schmertmann's et al method (1978) as directed by USEPA; this method strictly applies for a rigid axisymmetric load of finite extent. In order to use the method, the hide pile was approximated as a circle of equivalent area. Schmertmann's method also relies upon static cone resistance data. Such data were not available in the present case and was approximated from the SPT 'N' values using the correlations presented by Robertson, et al. (1983) and Kasim, et al. (1986). Settlements were calculated for maximum and minimum 'N' value profiles in order to compute maximum differential settlements.

The maximum differential settlement obtained by the one-dimensional method is 0.01 feet in a distance of 100 feet, while the maximum predicted by Schmertmann method is 0.01 feet in a distance of 140 feet. This indicated that neither the integrity of the cap nor the drainage gradients would be adversely affected by the maximum credible settlements which are conservatively estimated by the one-dimensional method. Preloading of the hide piles prior to construction of the cap is therefore not necessary.

12.3.5 Cover Drainage

Calculations of the required thickness and hydraulic conductivity of the drainage layer in the ROD cover were carried out using the HELP (Hydrologic Evaluation of Landfill Performance) computer program developed by the U.S. Army Corps of Engineers. Output data from the program is included in Appendix 12-F. The HELP model is an automated water balance method which allows computation on a daily basis over a period of years, providing more representative results than manual water balance calculations which are typically performed on a monthly basis for a single year. Water balance calculations, and the HELP model in particular, are generally used to evaluate potential leachate generation in landfills. In the present case, however, the method was used to provide a conservative verification of the adequacy of the drainage layer located between the cover soil and the geomembrane.

A one-dimensional model is inherent in the water balance method, so that only a single gradient can be used to compute surface runoff. In the present case the maximum overall drainage path length was used in conjunction with the minimum slope to be conservative. Using a drainage layer permeability of 1×10^{-3} cm/sec, the minimum specified in the RDAP, lead to a required drainage layer thickness in excess of 8 feet. Assuming a drainage layer thickness of 12 inches, the minimum permeability required to maintain the maximum head within the soil cover was approximately 5×10^{-2} cm/sec.

The capacity of the geocomposite drainage layer and the required granular medium may be compared via the transmissivity, which is the product of the hydraulic conductivity and the thickness. The transmissivity of the required granular drainage layer is therefore 1.5×10^{-4} m^2/sec. A geocomposite alternative such as Tex-Net TN3001CN (manufactured by Fluid Seal Systems Inc.) or equivalent, has a transmissivity of 1×10^{-3} m^2/sec under a surcharge load of 2,000 psf. The synthetic drainage medium therefore has a transmissivity one order of magnitude higher than required by conservative calculations.

As a further check, the geocomposite drain was directly modelled by two alternative methods:

a. Modelling the physical thickness of the geocomposite in conjunction with its actual transmissivity and porosity, a negligible wilting point and field capacity.

b. Modelling the geocomposite as a 12-inch thick gravel layer and scaling the permeability to provide a transmissivity equivalent to the geocomposite.

The maximum head over the geomembrane under 20-year conditions was 10.5 inches, calculated by method 'a' above, confirming that the proposed design of the geocomposite drainage layer is conservative.

12.3.6 Chemical Compatibility of Geomembrane

The gases emitted from the Hide Piles were discussed in the Remedial Investigation Phase II, Volume 1, Section 4, p. VI-10, Prepared by Roux Associates for Stauffer Chemical Company (1984).

The gaseous release rates from boreholes totalled 1.82 scfm (standard cubic feet per minute) for the East Hide Pile. The gases emitted from the East Hide Pile and West Hide Pile boreholes were listed in Table IV-2 of the Remedial Investigation Phase II, Volume I, Section 4 as cited above and include the following constituents:

Compound	Greatest Concentration
Hydrogen Sulfide	21,000 ppm
2-Propanethiol	180 ppm
Methanethiol	110 ppm
Ethanethiol	19 ppm
Carbon Oxide Sulfide	13 ppm
Carbon Disulfide	11 ppm
Dimethyl Disulfide	7.8 ppm
2-Butanethiol Isomer	5.5 ppm
Benzene	2.3 ppm
Toluene	1.6 ppm
Methyl Furan Isomer	1.4 ppm
Trichlorofluoromethane	0.63 ppm

The chemical compatibility of the HDPE geomembrane was evaluated from the available literature and discussions with the following manufacturers and research organizations:

Geosynthetic Research Institute
National Seal Company
Gundle Lining Systems
Union Carbide
SLT North America

The information obtained relates to both transmissibility and the effect on mechanical properties over time and is summarized in the following paragraphs.

The Geosynthetic Research Institute (GRI) provided various tests of compatibility of HDPE with concentrated liquid benzene and toluene. After an immersion period of three months, HDPE immersed in benzene shows good performance in tensile strength and weight tests. The performance of specimens immersed in liquid toluene was classified as poor. GRI also provided data evaluating the rate of water vapor transport through HDPE. A 30 mil HDPE geomembrane had a vapor transport value of 0.02 g/m^2-day, while a 96 mil HDPE geomembrane had a vapor transport value of 0.006 g/m^2-day.

SLT North America conducted tests for chemical compatibility and found that HDPE has excellent resistance to immersion in gaseous hydrogen sulfide at temperatures of 68 degrees F and 140 degrees F. SLT North America also indicated that HDPE has good resistance to chlorinated hydrocarbons. Tests for methane gas permeability conducted by SLT North America indicated an average value of 2.06 cc/100 sq in/24 hours Atm for 60 mil sheet.

Tests have been conducted by Union Carbide on the contact of hydrogen sulfide with HDPE geomembrane. Chemically, there is nothing for the hydrogen sulfide to react with in the polyethylene. Union Carbide has concluded that the hydrogen sulfide behaves like water and does not penetrate polyethylene. In terms of vapor transmissibility, hydrogen sulfide gas is considered less likely to emit through a HDPE geomembrane than water vapor.

Gundle Lining Systems conducted chemical immersion tests on 60 mil HDPE for a period of the thirty days. The effect on mechanical properties of the HDPE was only slight after being immersed in concentrated sulfuric acid. Gundle also conducted chemical immersion tests of their HDPE product Gundline HD. The product was immersed in a concentrated mixture of sodium sulfide and sodium hydroxide known as "Black Liquor". The mechanical properties of the Gundline HD were not affected after a period of sixty days.

In conclusion, the chemical compatibility of the proposed HDPE geomembrane with the identified gases from the East Hide Pile appears to be good. Likely vapor transmissibility through the HDPE geomembrane is low and conservative calculations indicate that the volume of transmitted gas would be below detection limits.

12.4 IMPERMEABLE COVER DESIGN

12.4.1 Impermeable Cover Grading

The East Hide Pile is located in the north-central portion of the Site, close to the Site boundary. The northern and western sides of the hide pile are bounded by Wetland 1C. The West Branch of the Aberjona River (Wetland 2A) runs along the southern edge of the hide pile. A bedrock outcrop exists to the east of the hide pile. Boston Edison Right-of-Way No. 14 runs east-northeast across the hide pile. The location and extent of the East Hide Pile, as defined by the Consent Decree, is shown on Sheet 11-2A.

The existing peak elevation of the hide pile is around 108 feet, sloping to Wetland 1C with overall slopes of around 2.5H:1V to 3H:1V increasing locally to 1.5H:1V.

The impermeable cover extends over the full area of the East Hide Pile as defined in Attachment F of the Consent Decree, and to the base of the topographic pile where this covers a larger area.

The grading plan for the impermeable cover on the East Hide Pile has been designed to: 1) increase the stability of the slopes, 2) minimize impact on wetland functionality, and 3) optimize constructability.

A grading plan incorporating a minimum slope of 3 percent and a maximum slope of 33 percent has been designed for the impermeable cover on the East Hide Pile. The relatively flat areas near the top of the East Hide Pile are sloped at a minimum of 3 percent to promote efficient drainage. A maximum slope of 33 percent was chosen in cover areas to achieve a reasonable slope stability factor of safety as discussed in Sections 12.3.1.2 and 12.3.1.3.

This grading plan is most suitable for wetlands revegetation and wildlife accessibility to the wetlands, since it avoids vertical or semi-vertical retaining structures and, at the same time, reduces to a minimum encroachment into the wetlands. The effects of this construction on the wetlands are minimized, but will involve synthetics, soil, and rip-rap protection placed along the water's edge, and in isolated areas, into the standing water.

Constructability is maximized by the use of long straight contours and smooth constant slopes. The design avoids any cutting of the hide piles. Construction considerations are discussed, in detail, in Section 12.4.5.

The grading plan for the East Hide Pile is presented on Sheet 12-1 and cross-sections are shown on Sheets 12-2 through 12-4.

12.4.2 Surface Water Drainage

The surface water management design consists of a rip-rap drainage channel (see Details 1 and 2, Sheet 12-8) around the northern and eastern perimeter of the hide pile, a rip-rap toe drain along the edge of Wetland 1C (see Details 2 and 3, Sheet 12-7), and a collection pipe to transmit discharge from the geocomposite drainage layer. The design of these features is discussed in the following sections.

12.4.2.1 Drainage Channel

The rip-rap drainage channel receives flow from: a) surface water run-off from the surrounding natural ground to the east of the hide pile and from the cover surface and, b) water collected in the geocomposite drainage layer in the eastern section of the hide pile. Flow is divided in the channel adjacent to the gas treatment system (Sheet 12-1) and water is conveyed to the north and south of the hide pile. The channel discharges to Wetland 1C at the north side of the East Hide Pile through a transition (see Detail 3, Sheet 12-8) to the remediated wetland. At the southern end, the channel discharges via an 18 inch diameter concrete culvert to an existing channel that discharges to the Western Branch of the Aberjona River. Along part of the northeastern edge of the East Hide Pile, the channel is routed via an 18 inch diameter concrete culvert under the regraded slope so as to limit construction to within the Site boundary. Channel profiles are presented on Sheets 12-5 and 12-6.

The rip-rap drainage channel was designed using the United States Department of Agriculture, Soil Conservation Service, Technical Release TR55 hydrologic program (SCS, 1986). TR55 was used to estimate the maximum flow in the channel based on a 24 hour, 100 year storm. The size and shape of the channel, the maximum depth of flow and type of channel lining were found by using Manning's equation with the maximum expected flow. The TR55 program output and associated calculations are included in Appendix 12-G.

The two sections of drainage channel running to the south and to the northwest along the eastern side of the hide pile have a base width of 2 feet and a depth of 1.5 feet, with 2H:1V side slopes. The base width of the north channel increases to 4 feet along the northern side of the hide pile in the section downstream of the culvert. The entire length of the channel is rip-rap lined. The rip-rap is 1.5 feet thick, with stone having a mean diameter of 0.5 feet. The cover tie-in is shown on Sheet 12-7 Detail 4 and the channel cross sections may be found on Sheet 12-8, Details 1 and 2.

12.4.2.2 Geocomposite Discharge

The impermeable cover section includes a geocomposite drainage layer to collect water which infiltrates the cover soil. Discharge from the geocomposite is conducted to the wetlands in several ways depending upon location. Along the west side of the East Hide Pile the drainage layer will discharge into the wetlands via the rip-rap toe drain (see Details 2 and 3, Sheet 12-7). The Western Branch of the Aberjona River, located along the southern edge of the East Hide Pile, will be remediated with a gravel/cobble lining. The geocomposite is to be extended to discharge directly into the channel. A drainage collection pipe (see Details 5 and 6, Sheet 12-7) is utilized to intercept flow from the geocomposite for a short section along the northeast edge of the hide pile parallel to the 18 inch diameter concrete culvert. Along the eastern and northern edge of the East Hide Pile the geocomposite discharges into the rip-rap channel provided for surface water drainage.

12.4.2.3 Toe Drain

The rip-rap toe drain provides a discharge media from the geocomposite drainage layer to the existing wetlands, and provides protection of the cover system from water at the toe of slope. The mean diameter of the rip-rap stone is 0.5 feet with an average thickness of 16 inches. The rip-rap will extend a minimum of 5 feet horizontally up the slope (Sheet 12-1). A 16 ounce/square yard nonwoven geotextile is utilized to prevent migration of fine particles into the rip-rap layer. Details 2 and 3 on Sheet 12-7 show tie-ins of the toe drain to Wetland 1C.

12.4.3 Gravel Access Road

A gravel access road is located along the east side of the East Hide Pile (see Sheet 12-1). The road will function to provide access to the gas treatment system at the crest of the hide pile and for maintenance to the cover system. Outside the cap limits, the road cross section consists of a 3 inch gravel layer (AASHTO #57 or equivalent), as shown in Detail 4, Sheet 12-8. To maintain the permeable cover system requirements, the cross section of the access road within the cap limits consists, from bottom to top, of a 16 ounce/square yard nonwoven geotextile, a 13 inch structural fill layer and a 3 inch gravel layer (AASHTO #57), as shown in Detail 5, Sheet 12-8. Calculations for determining the road cross section may be found in Appendix 12-H. In both cases, the gravel shall be placed on a competent subgrade as approved by the Design Engineer.

12.4.4 Erosion And Sedimentation Control

Proper erosion and sedimentation control measures will be maintained during the construction of the remedy. Straw bales and silt fences (see Details 6 and 7, Sheet 12-8) will be placed along the perimeter of the hide pile to prevent the transport of sediments into the adjacent wetland. The straw bales and silt fences will be properly maintained and replaced as needed until the construction of the cover system has been completed and vegetation has developed. If necessary, temporary erosion control measures such as erosion mat and diversion swales at the crest of slope should be utilized prior to permanent vegetation. Additional erosion and sedimentation details are provided in the Specifications.

12.4.5 Construction Considerations

Prior to placement of the impermeable cover, all existing above ground vegetation is to be cleared, tree trunks cut to ground surface, and the root mat left in place. Woody material from above ground and other vegetation will be chipped and composted for later placement as fill under the permeable cover.

Fill material to be placed to grade the slopes will be compacted in horizontal layers not greater than 12 inches loose thickness to a minimum density equivalent to 95 percent of the Standard Proctor. Prior to construction of the cover, hide pile slopes equal to or flatter than 40 percent will be proof rolled to compact the Surficial Materials. Where existing slopes are steeper than 40 percent, the thickness of fill will be significant and will function to prevent surface sloughing. A roller of 10 ton minimum weight will be used for proof rolling. All fill placement and cover construction will be carried out from toe to crest of the slopes, so that the slope stability of the hide pile is not temporarily reduced by construction operations. Existing vegetation shall be cleared in stages just in advance of the filling operation.

Material excavated elsewhere on the Site will be the primary source of fill to regrade the slopes of the hide pile. The fill material on the slopes shall be granular soil, free of any deleterious materials such as wood, construction debris and saturated soils. Specific requirements for fill materials are presented in the Specifications.

Monitoring well OW-32 located in the southwest corner of the East Hide Pile (see Sheet 11-6) and existing gas vents will be decommissioned prior to placement of the cover on the hide pile. The procedure for decommissioning is discussed in the Specifications.

Boston Edison Right-of-Way No. 14 runs east-northeast across the hide pile. The two power poles located on the hide pile are to be removed and relocated outside the cover area by the Boston Edison Company prior to placement of the cover on the hide pile.

Graded gravel for the gas collection layer (AASHTO #8) will be carefully placed on the prepared subgrade. Gas collection pipes are to be wrapped with a 10 ounce per square yard nonwoven geotextile to prevent infiltration of fines into the collection pipe network. The geotextile will be sewn along its length and at seams between adjacent sheets. After completion of the geotextile wrap, gravel shall be carefully placed around the pipes to achieve a 12 inch thickness. Locations of the pipes shall be clearly marked and subsequent construction of the cover should be organized to avoid damage to the pipes. Installation of the piping, geotextile, and gravel collection layer shall be closely monitored in accordance with the Specifications.

The 10 ounce per square yard geotextile will then be placed to cover the gas collection layer. All seams in the geotextile shall be carefully sewn and reviewed for quality control by the Q.A. Inspector.

Installation of the 60 mil textured HDPE geomembrane will include deployment of the sheet and heat seaming of all seams. Contractor personnel completing the geomembrane installation shall be experienced with textured HDPE, and all seaming personnel shall be qualified on the project prior to actually performing any seaming of HDPE sheet in place. The seaming process will be carefully monitored, with all seams being tested along their length by vacuum box or air pressure testing. Additionally specimens will be obtained at intervals from the seams for destructive tests to ensure seam quality. Any seams which do not pass the required QA/QC testing will be cap stripped.

The geocomposite drainage layer will be installed above the seamed geomembrane. Contractor personnel will have to complete this operation carefully to minimize potential for damage to the geomembrane. Adjacent sheets of geocomposite will be seamed by overlapping and tying the geonet together with plastic ties and sewing the upper geotextile sheets. When seaming between a geotextile and a geocomposite is required, the geotextile will be sewn to one of the geotextiles of the geocomposite. All seaming will be reviewed by the Q.A. Inspector.

The soil cover will then be placed directly over the geocomposite. The soil shall be placed in a manner that minimizes imposed stress on the underlying geocomposite and geomembrane, by using low ground pressure earth moving equipment and maintaining a minimum thickness of 12 inches of soil between placing equipment and the geocomposite at all times. So as to enhance stability of the hide pile, cover soil shall be placed from the base of the pile toward the top. Cover soil will be nominally compacted by the action of the placing equipment only.

In areas where the impermeable cover ties into wetlands or perimeter drainage facilities, careful construction will be required to properly build the transition details. In these areas a number of geotextiles will have to be joined with multiple seams all of which will be inspected. In areas of the wetlands, subgrades are likely to be easily disturbed so it is important that the contractor minimize potential disturbance by the use of properly sized and operated equipment.

The access road to the gas treatment system will be constructed of compacted fill placed to reach road subgrade and capped with a minimum of 3 inches of graded gravel surfacing. The road will tie into the permeable cover to be constructed to the east of the East Hide Pile.

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Golder Associates Inc., 1990b. Remedial Design Work Plan, Industri-Plex Site, Woburn, MA, July.

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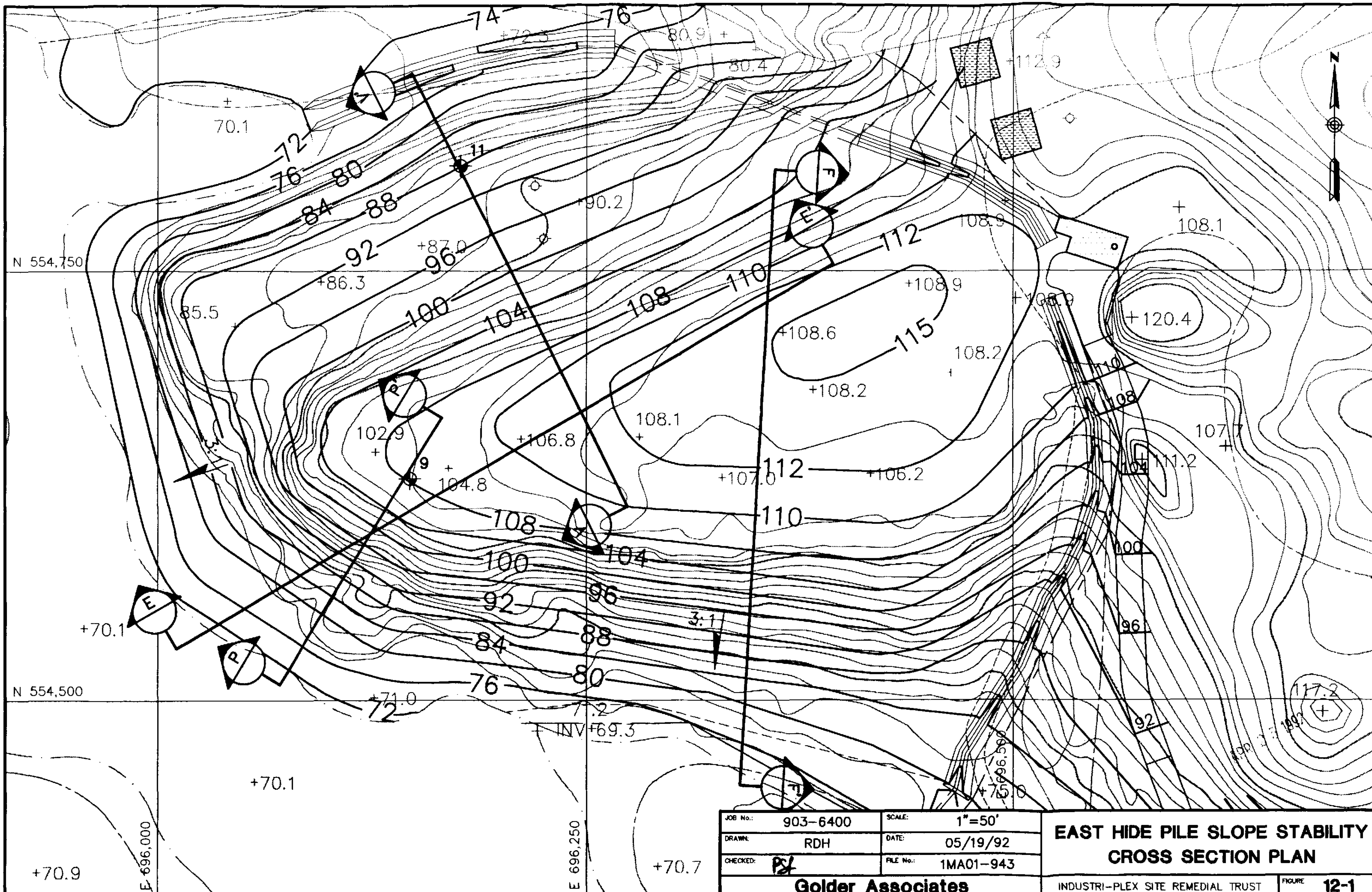
TABLE 12-1 EAST HIDE PILE STABILITY				
SECTION	GROUNDWATER CONDITION	FAILURE MODE	FACTOR OF SAFETY	
			EXISTING	REMEDIATED
F-F'	Long Term	Surface Sloughing	1.0	N/A
		Circular	1.9	2.3
		Non-Circular	2.0	--
	Perched Water Table	Surface Sloughing		
		- seepage emerging from slope	0.2	N/A
		- seepage parallel to slope	0.5	N/A
		Circular	1.9	N/A
E-E'	Long Term	Circular	2.1	--
P-P'	Long Term	Circular	1.5	2.2
V-V'	Long Term	Circular	1.8	2.8



JOB No.: 903-6400	SCALE: 1"=50'	EAST HIDE PILE SLOPE STABILITY CROSS SECTION PLAN	
DRAWN: RDH	DATE: 05/19/92		
CHECKED: PSL	FILE No.: 1MA01-943		
Golder Associates		INDUSTRI-PLEX SITE REMEDIAL TRUST	FIGURE 12-1

APPENDIX 12-A

Impermeable Cap Requirements

IMPERMEABLE CAP REQUIREMENTS

This section is reproduced from the PDI Task S-3 Interim Final Report (Golder Associates, 1990).

2.3 Impermeable Cap Requirements

The RDAP specifies an impermeable cap will be placed over the East Hide Pile in order to mitigate odors and collect gases to be treated. The impermeable cap will include (from bottom to top):

1. A gas collection layer;
2. A bedding layer;
3. An impermeable synthetic geomembrane;
4. A middle drainage layer; and,
5. A vegetated top layer.

The RDAP divides the cap components into three layers; a bottom impermeable layer consisting of the gas collection layer, bedding layer, and geomembrane; a middle drainage layer; and a vegetated top layer. The following sections will discuss the functions and requirements of the three cap layers.

2.3.1 Impermeable Layer

The bottom impermeable layer shall consist of the following in accordance with Attachment A of the RDAP:

1. A gas collection layer;

2. A bedding layer designed to prevent clogging of the underlying gas collection layer, and provide a stable base for overlying layers. The gas collection layer can also function as the bedding layer, provided it will support the weight of the cap and not abrade the overlying geomembrane;

3. An impermeable synthetic membrane having a minimum thickness of 40 mil; and,

4. A final grade of at least 2 percent.

The purpose of the gas collection system is to collect and convey the gas generated from the East Hide Pile through a network of piping to the temporary gas treatment system. The Remedial Design Work Plan (Golder Associates, 1990a) indicates that the piping shall be 6 inches in diameter and embedded in gravel. The gravel will allow gas to flow to the piping system. The thickness of gravel is not specifically mentioned in any document, however, the ROD indicates a gravel layer 12 inches thick in Figure 12. It is anticipated that the gravel layer would be a minimum of 12 inches thick to allow for sufficient coverage around the piping system.

One of the most important properties for a gas collection layer is its absolute permeability (generally expressed in cm^2), that depends exclusively on the properties of the porous media and measures the flow capacity of any fluid through that media. When applied to a specific fluid, a coefficient of permeability (generally expressed in cm/sec) is defined, which also depends on the fluid properties. In the case of liquid fluids, the coefficient of permeability is generally called hydraulic conductivity. Hydraulic conductivity values determined for one fluid allow the hydraulic conductivity for any other fluid to be calculated.

For the borrow areas potentially usable for the gas collection layer in this project, hydraulic conductivity tests have been conducted on samples using distilled water, as an indirect measurement of their flow capacity, and from which hydraulic conductivity values could be determined for other fluids during the design stage. Since no specification of absolute permeability or hydraulic conductivity has been given in any of the governing documents, a hydraulic conductivity of 1.0×10^{-3} cm/sec is proposed as the minimum required for this layer.

As stated in the RDAP, the function of the bedding layer is to prevent clogging of the underlying gas collection system and provide a stable base for overlying layers. Since a geomembrane overlies the bedding layer, its function to prevent clogging is redundant. Also, the load from overlying layers is minimal and the gas collection system could also function as the bedding layer. Therefore, the need for a bedding layer will be re-evaluated as part of the design.

The property of importance for the bedding layer is the gradation and texture of the particles. A coarse and angular bedding layer may abrade and inbed into the overlying geomembrane, compromising its integrity. Also, a bedding layer that has a finer particle size distribution than the gas collection layer may migrate downward and clog the gas collection layer. As suggested in the Remedial Design Work Plan (p. 23) it may be advantageous to use a geotextile directly on top of the bedding layer to provide a cushion and clean working surface for the placement of the geomembrane. If the bedding layer contains finer particles than the underlying gravel, the use of a geotextile between the bedding layer and the gas collection layer would prevent particle migration downward.

A geomembrane having a minimal thickness of 40 mil is required by the RDAP to be placed on top of the bedding layer. The function of the geomembrane is to establish impermeability to prevent the migration of gases to the air and percolation of water into the East Hide Pile. No material type is specified. The choice for a geomembrane is basically related to its durability, strength, and constructability. The durability of a geomembrane is related to its chemical, physical, and mechanical properties. The mechanical properties are related, in part, to the sheet thickness. Strength properties and survivability are increased with a thicker sheet.

High density polyethylene (HDPE) is widely used for landfill liners and closures, because it is more resistant to most chemical substances than other geomembrane polymers (Reference 8). HDPE is also a low cost material relative to other liner options.

Considering the advantages discussed above, as well as Golder's experience, HDPE is tentatively recommended as the impermeable layer component. There are various properties of importance for HDPE including thickness, strength, and puncture resistance. The minimum standards for HDPE flexible membrane liner are outlined in the National Sanitation Foundation (NSF) Standard Number 54. Typically thicknesses for HDPE liners are 40 or 60 mils. Generally, field testing allows for a variance in thickness of 10 percent. The minimum strength requirements for 40 and 60 mil HDPE are listed below:

	40 mil	60 mil
Tensile Strength at Yield (lb/in. width)	70	120
Tensile Strength at Break (lb/in. width)	120	180
Elongation at Yield (Percent)	10	10
Elongation at Break (Percent)	500	500

The NSF does not give minimum requirements for puncture resistance. Typically landfill liner specifications for geomembranes require puncture resistance of 40 and 60 pounds for 40 and 60 mil HDPE, respectively.

2.3.2 Middle Drainage Layer

A drainage layer is required to be placed on top of the geomembrane. The RDAP specifies in Attachment A that the middle drainage layer shall be:

"(1) of a thickness designed to accommodate the expected amount of settling and the maximum volume of water that could enter the drainage layer, but in any event no less than 6 (six) inches;

(2) consisting of a material whose permeability exceeds 1 x 10^{-3} cm/sec., i.e., a sand in the SW or SP range of the Unified Soil Classification System or coarser material;

(3) designed and constructed with a bottom slope of at least 2 percent; and,

(4) designed and constructed to prevent clogging."

The function of the drainage layer is to transmit the maximum volume of water that could enter the system to prevent ponding effects. The significant properties of the drainage layer are gradation and hydraulic conductivity as specified by the RDAP. The gradation of the drainage layer is important since it is related to permeability. The angularity is also important for the survivability of the underlying geomembrane, to minimize abrasions and scratches during installation.

The thickness of the drainage layer will depend on design calculations. The RDAP specifies a thickness of no less than 6 inches. It must be considered that the thickness of cover over the geomembrane should be, at a minimum, equal to the depth of frost penetration to allow for a functioning drainage layer throughout the year. The ACDR indicated that the average frost depth will not penetrate a 16 inch cover.

2.3.3 Vegetated Top Layer

A vegetated layer is required to be placed above the drainage layer. The RDAP in Attachment A specifies the vegetated top layer shall be:

"(1) of a thickness designed to accommodate the maximum depth of root penetration and the rate of anticipated soil loss, but in any event no less than 6 inches;

(2) capable of supporting vegetation that minimizes erosion and minimizes continued maintenance;

(3) planted with a persistent species with roots that will not penetrate beyond the vegetative and drainage layers;

(4) designed and constructed with a top slope of between three (3) percent and five (5) percent after settling and subsidence or, if designed and constructed with a slope of greater than five (5) percent, an expected soil loss of less than two (2) tons/acre/year using the USDA universal soil loss equation; and,

(5) designed and constructed with a surface drainage system capable of conducting effective run-off across the cap."

The functions and requirements of the upper vegetated layer are well outlined above. The properties relative to these functions include gradation, organic content and soil fertility. These properties are important to properly design a consistent seed and fertilizer program for rapid and persistent vegetative growth.

APPENDIX 12-B

Existing Slope Stability Calculations

Shear Strength Parameters for Fill and Hide Residue

Objective : To estimate ϕ' and c' for the Fill and Hide Residue from the results of triaxial tests plotted on a p'-q plot, where :

ϕ' = effective angle of shearing resistance
c' = effective cohesive strength.

Reference : Lambe-Whitman, Soil Mechanics, 1969, "Use of a p-q Diagram," p. 141-2.

Method : Four types of triaxial test were performed on the Fill and Hide Residue :

1. Undisturbed Consolidated-Drained
2. Undisturbed Consolidated-Undrained with pore pressure measurement
3. Remolded C-D
4. Remolded C-U w/o p.p.m.

The failure points were plotted on a p'-q plot, where:

$$p' = \frac{\sigma_1' + \sigma_3'}{2} \qquad q = \frac{\sigma_1' - \sigma_3'}{2}$$

with:

p' = effective normal stress at failure
q = shear stress
σ_1' = major principal effective stress at failure
σ_3' = minor " " " " "

→ From the plotted data, a "best fit" line was drawn through the data to determine the slope (ψ) and intercept (d) of the p'-q plot.

ϕ' and c' were determined from (ψ) and (d) using the equations ;

$$\sin\phi' = \tan\psi \quad \text{and} \quad c' = \frac{d}{\cos\phi'}.$$

A lower bound line was drawn through the data to determine the lower bound ϕ' and c' values using the same relationships as above.

Golder Associates	SUBJECT Estimation of ϕ' and c' From p'-q plot		
	Job No. 703 6700 Ref. ISRT	Made by RD Checked AH Reviewed PER	Date 12-18-91 Sheet 2 of 3

Calculations :

1) "Best Fit" line : $\psi = 31°$ and $d = 1.6$ psi

$$\sin\phi' = \tan\psi$$
$$\sin\phi' = \tan(31°)$$
$$\phi' = 36.9° \approx \underline{\underline{37°}}$$

$$c' = \frac{d}{\cos\phi}$$

$$c = \frac{1.6}{\cos(37)} = \underline{\underline{2}} \text{ psi}$$

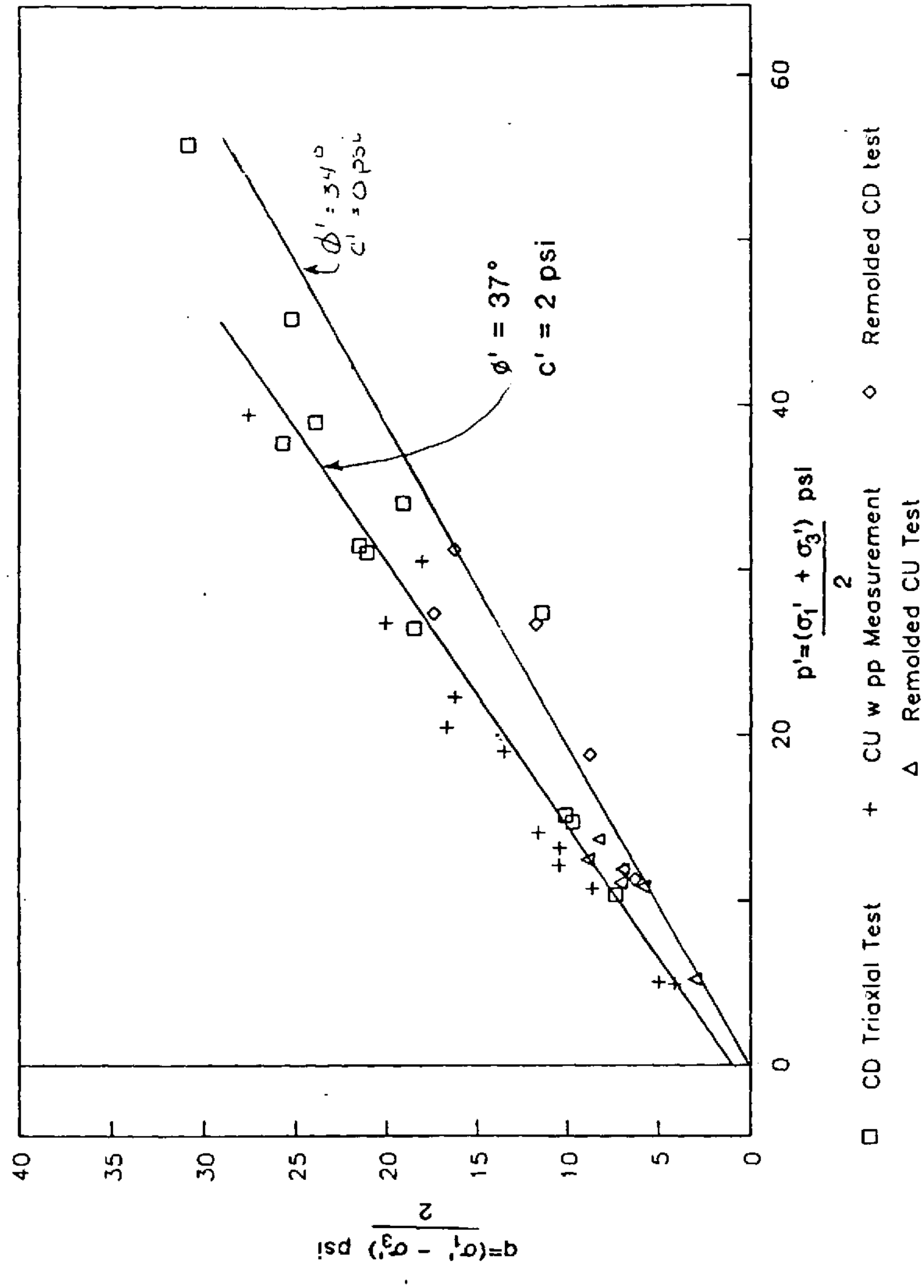
2) Lower Bound line : $\psi = 29°$ and $d = 0$

$$\sin\phi' = \tan\psi$$
$$\sin\phi' = \tan(29)$$
$$\phi' = 33.7° \approx \underline{\underline{34°}}$$

$$c' = \frac{d}{\cos\phi}$$

$$c' = \frac{0}{\cos(34)} = \underline{\underline{0}} \text{ psi}$$

3 of 3



JOB No.: 893-6255	SCALE: N/A	**SHEAR STRENGTH p'-q PLOT FILL AND HIDE RESIDUE**	
DRAWN: MRM	DATE: 09/14/90		
CHECKED: RAC	DWG. No.: MA01-156		
Golder Associates		ISRT/WOBURN/MA	FIGURE

Golder Associates	SUBJECT ESTIMATE ϕ' FOR FILL & HIDE RESIDUE		
	Job No. 903-6700	Made by RAC	Date
	Ref.	Checked VE97	Sheet 1 of 4
		Reviewed MR	

OBJECTIVE: TO ESTIMATE ϕ' FOR THE FILL & HIDE RESIDUE USING N-VALUES BASED ON SCHMERTMANN, 1975

REFERENCE: 1) MEASUREMENT OF IN-SITU SHEAR STRENGTH
JOHN H SCHMERTMANN, 1975

ASSUMPTIONS

1) METHOD FOR ESTIMATING ϕ' FROM SPT VALUES DOES NOT APPLY FOR DEPTHS LESS THAN 2m.

2) USE SPT VALUES FROM EAST HIDE PILE.

3) ASSUME WATER TABLE DEPTH AT 23'

CALCULATIONS:

1) CALCULATE OVERBURDEN PRESSURE AT 10', 20', 30', 35'

σ_o' @ 10' = (125pcf)(10') = 1250 psf = 0.625 Kg/cm²

σ_o' @ 20' = (125pcf)(20') = 2500 psf = 1.25 Kg/cm²

σ_o' @ 30' = (125pcf)(23') + (125-62.4)(7) = 3313 psf = 1.66 Kg/cm²

σ_o' @ 35' = (125pcf)(23) + (125-62.4)(12) = 3626 psf = 1.8 Kg/cm²

2) DETERMINE N FROM ATTACHED SHEET (low values considered subsequently)

10'	=	7.3
20'	=	10
30'	=	20
35'	=	24.5

CALCULATIONS (CONT'D)

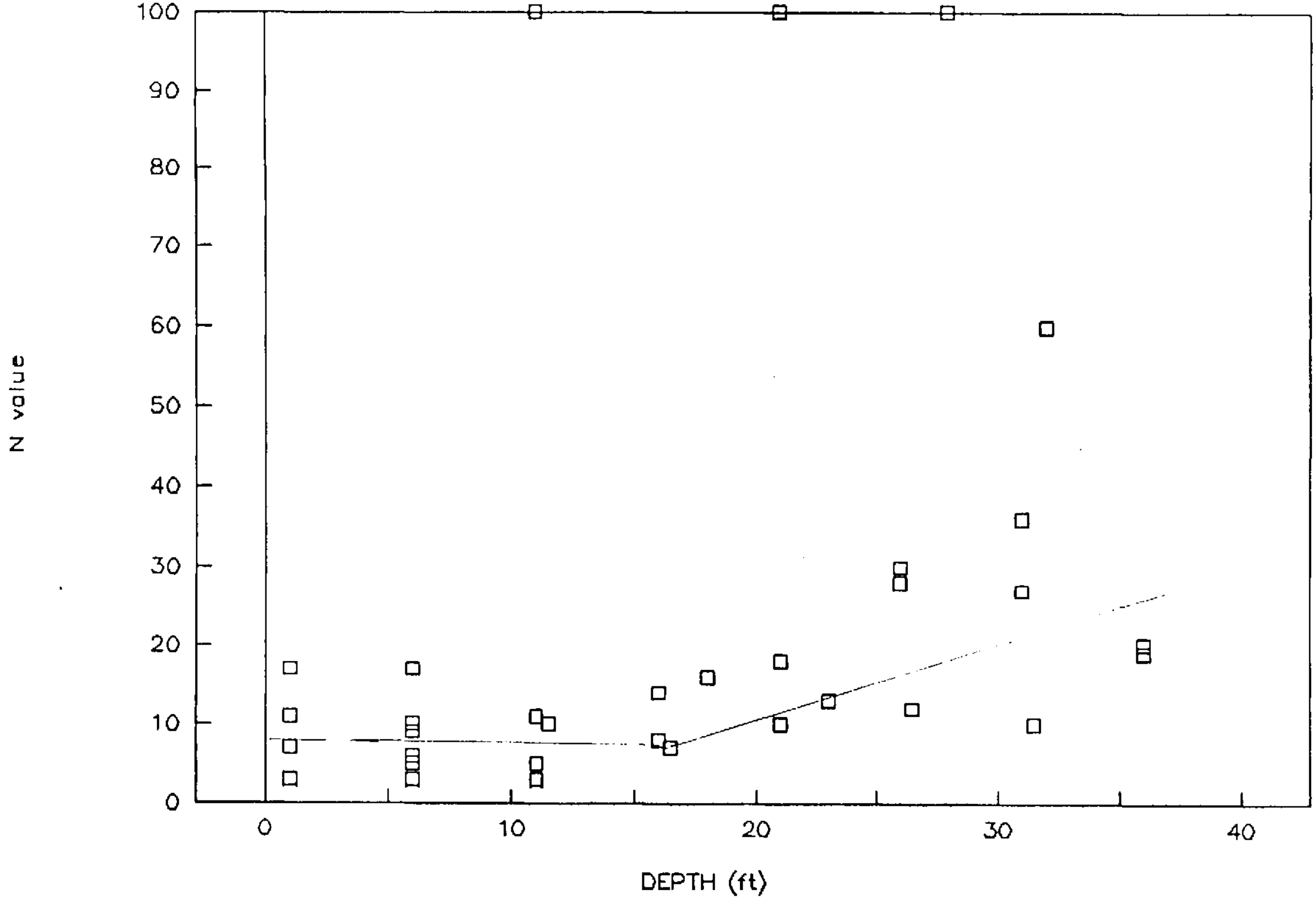
3) DETERMINE Ø' FROM ATTACHED TABLE

DEPTH	N	Ø'
10'	7.3	35°
20'	10	34°
30'	20	37.5°
35'	24.5	38.5°

FOR OVERALL STABILITY CALCULATIONS TAKE Ø' = 35°.

EAST HIDE PILE

FILL AND HIDE RESIDUE

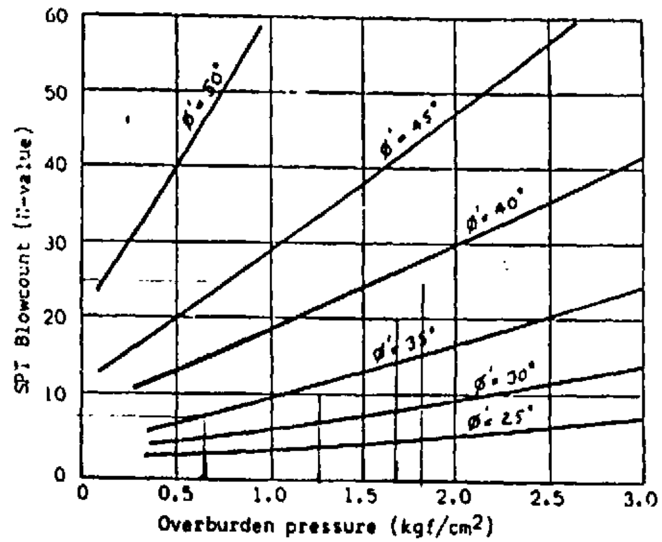


shear strength from the SPT must be treated as just that -- an estimate. However, the pressure of circumstances often forces engineers to make such estimates and the writer offers the following as the state-of-the-art on this subject.

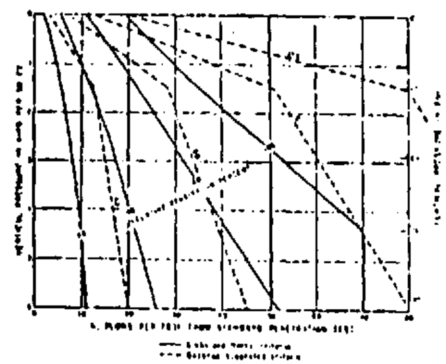
2.21 <u>ϕ' in Sands</u>: As part of his very thorough review of the state-of-the-art of the SPT, deMello (1971, pp. 26-31) studied the published N-ϕ correlation data -- which he found meager. He reviewed the data of Gibbs and Holtz (1957), assumed an equation based on Prandtl-Caquot-Buisman idealized theory, and found by statistical evaluation that the G & H data fit the equation with good confidence. <u>Figure 1</u> herein presents this correlation, as adapted from deMello's Figure 11. He then checked this correlation prediction method against mostly unpublished data from private sources and found reasonable agreement provided one considered <u>Figure 1</u> as usually conservative and does not apply it to SPTs at "very shallow depths" (writer's interpretation = less than 2 m.).

The above can produce only rough estimates of ϕ' in sands. An experienced engineer with a sample in hand can perhaps estimate ϕ' triaxial with better accuracy. However, this SPT method does provide the engineer with a rough check and some documentation. But, variables other than ϕ' can have a great influence on the N-value. For example Barthélemy (1974) found in the Duke University chamber that N reduced about 55% when he added 10% mica to a sand, but kept the same triaxial ϕ' of about 39 degrees. Adding the mica reduced the triaxial initial tangent modulus, E_i, by about 60%. Obviously, a soil's compressibility has great importance.

One can also estimate ϕ' using relative density as an intermediate parameter, but deMello recommended against this common practice. The correlation most used for the estimate of relative density is that based on the research of Gibbs and Holtz (1957). To reduce conservatism at high D_r many engineers now include the modifications proposed by Bazaraa (1967). <u>Figure 2</u> presents these correlations in a form convenient for easily estimating relative density from the N-values. Because of general agreement with the philosophy expressed by Meyerhof (1965), most engineers no longer modify the N-value when testing below



<u>FIGURE 1</u> - METHOD FOR ESTIMATING ϕ' FROM SPT (based on deMello's 1971 analysis USBR data)



<u>FIGURE 2</u> - COMPARISON OF THE GIBBS & HOLTZ (1957) D_r CRITERIA AND THE BAZARAA (1967) SUGGESTED CRITERIA (as presented by Holtz and Gibbs, 1969, Fig. 26)

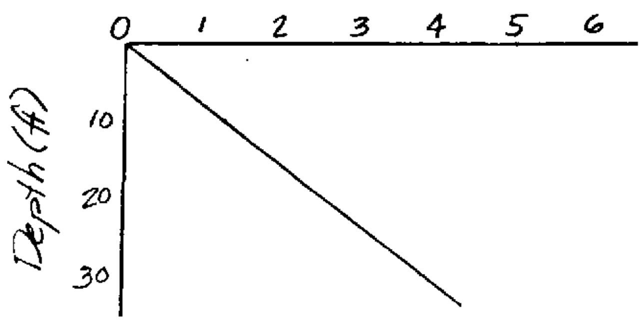
Golder Associates

SUBJECT ISRT – 30% Des. Rpt. – EPA Comments
Job No. 903-6400 | Made by VEE7 | Date 1-17-91
Ref. Question 10 | Checked PCN | Reviewed PER | Sheet 1 of 2

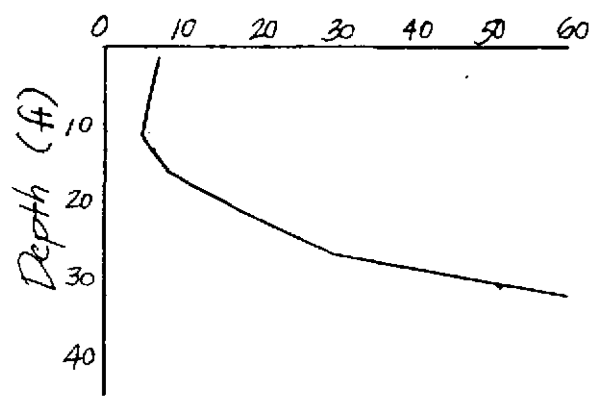
Objective: Using the blowcount, overburden pressure and depth relationship for boreholes #9 & #11, determine the ϕ for each hole using figure 1 from "In Situ Measurement Soil Properties, Specialty Conference of the Geotechnical Engineering Division. ASCE, June, 1975.

Procedure: For borehole #9,

Overburden Pressure (x1000 psf)(p_o')



N



For Depth = 10 ft, $N \approx 5$, $p_o' \approx 1250$ psf

For p_o', Convert psf to kgf/cm²

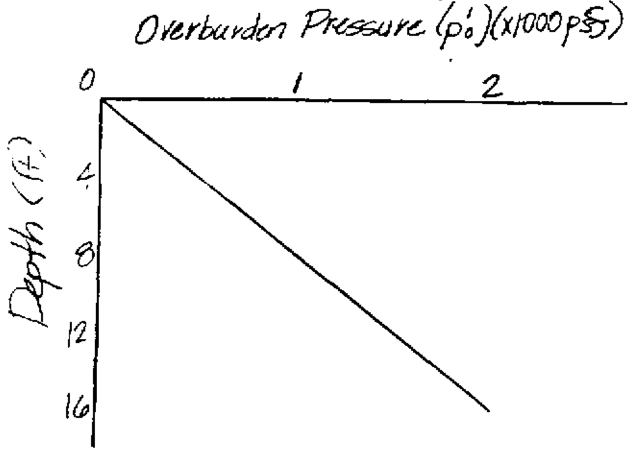
$$p_o' = 1250\ \cancel{psf}\left(\frac{1\ ft^2}{144\ in^2}\right)\left(\frac{1\ in^2}{2.54^2\ cm^2}\right)\left(\frac{4.45\ N}{1\ lb}\right)\left(\frac{1\ kgf}{9.81\ N}\right)$$

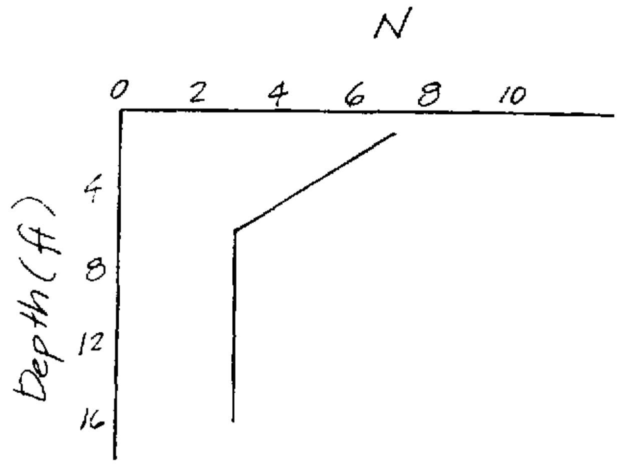
$p_o' = 0.610\ kgf/cm^2$ Use $p_o' = 0.6\ kgf/cm^2$

From figure 1, $\phi = 31°$

Golder Associates	SUBJECT ISRT – 30% Des Rpt – EPA Comments		
	Job No. 903-6400 Ref. Question 10	Made by VEET Checked FCN Reviewed MR	Date 1-17-91 Sheet 2 of 2

For borehole #11,





For Depth = 10ft, $N \approx 3$, $p_o' \approx 1240$ psf

For p_o', convert psf to kgf/cm²

$$p_o' = 1240\,psf\left(\frac{1\,ft^2}{144\,in^2}\right)\left(\frac{1\,in^2}{2.54^2\,cm^2}\right)\left(\frac{4.45\,N}{1\,lb}\right)\left(\frac{1\,kgf}{9.81\,N}\right)$$

$p_o' = 0.606$ kgf/cm²   Use $p_o' = 0.6$ kgf/cm²

From figure 1, $\phi = 26°$

This value is lower than the minimum ϕ value of 28° associated with granular soils

∴ Adopt $\phi = 28°$ for analysis

Section F-F'- Existing Conditions
Surface Sloughing - Long-Term and Perched Water Tables

$\cot\beta = \cot 26 = 2.05$

From the attached figure $A = 0.25$ for $r_u = 0.6$

$\therefore$ $FS = 0.96 \times 0.25 = 0.24$ // ✓

3) Perched Water Table, Seepage Parallel to Slope

Assume seepage surface is 80% of depth of sloughing

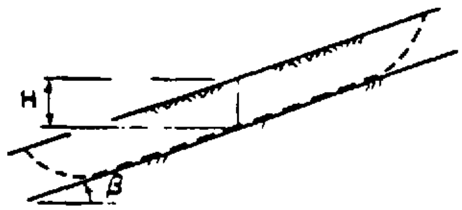
$$r_u = \frac{x}{T}\,\frac{\gamma_w}{\gamma}\cos^2\beta$$

$$= 0.8 \times \frac{62.4}{100}\cos^2 26 = 0.40$$

From the attached figure $A = 0.50$

$\therefore$ $FS = 0.96 \times 0.5 = 0.48$ // ✓

4/4



γ = total unit weight of soil

γ_w = unit weight of water

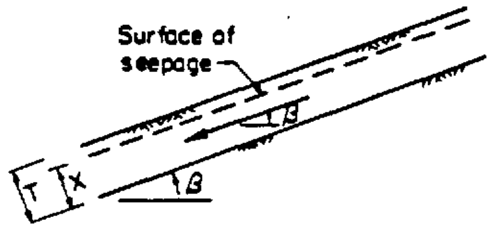
c' = cohesion intercept
ϕ' = friction angle } Effective Stress

r_u = pore pressure ratio = $\frac{u}{\gamma H}$

u = pore pressure at depth H

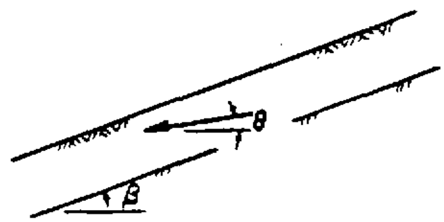
Steps:

1. Determine r_u from measured pore pressures or formulas at right
2. Determine A and B from charts below
3. Calculate $F = A \frac{\tan\phi'}{\tan\beta} + B \frac{c'}{\gamma H}$



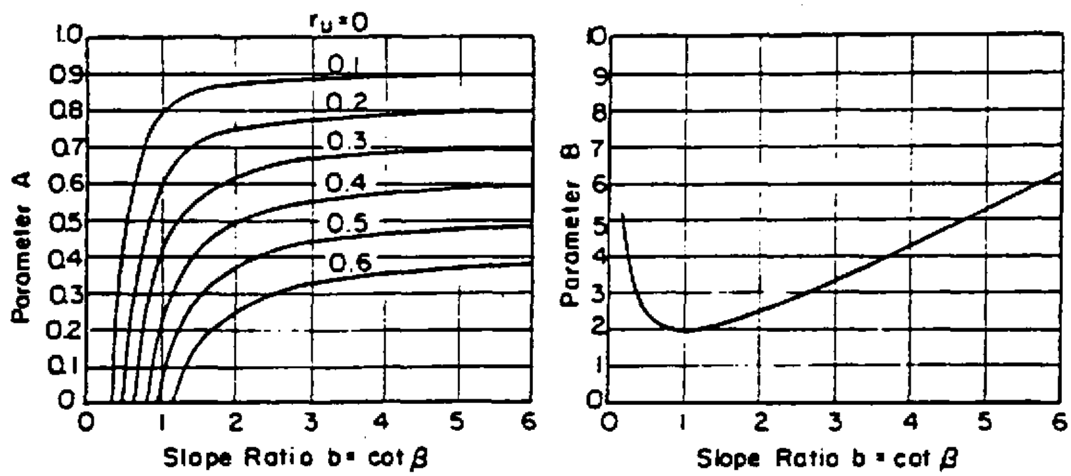
Seepage parallel to slope

$r_u = \frac{X}{T} \frac{\gamma_w}{\gamma} \cos^2\beta$



Seepage emerging from slope

$r_u = \frac{\gamma_w}{\gamma} \frac{1}{1 + \tan\beta \tan\theta}$



STABILITY CHARTS FOR INFINITE SLOPES.

Golder Associates

SUBJECT ISRT - East Hide Pile Stability		
Job No. 903-6400	Made by DOKL	Date 5/14/92
Ref. INDUSTRI-PLEX /WOBURN/MA	Checked RD	Sheet 1 of 4
	Reviewed PCR	

Objective: Evaluate the factor of safety of the existing slope of the East Hide Pile against shallow sloughing

Method:
1) Determine the steepest inclination of existing slope
2) Select the most representative soil parameters
3) Perform infinite slope analysis outlined in Ref 3. for the steepest existing slope.

References:

1) Golder, 1992 "Final Grading Plan." Drawing # 11-7 Proj # 903-6400
2) Golder, 1992 "Slope Stability Analyses." by DOKL. Proj # 903-6400
3) Duncan & Buchignani, "An Engineering Manual for Slope Stability Studies." University of Berkeley. 1975
4) Golder, 1990, "Pre-Design Investigation Task S-2 Stability of Hide Piles, Interim Final Report," Proj # 893-6255

Slope Angle (β): The inclination of the existing slope was obtained from Refs 1 and 2.

For section F-F' $\beta = 26°$
section E-E $\beta = 24°$
section V-V $\beta = 21°$
section P-P $\beta = 26°$

$\therefore$ the steepest slope is 26°

Material Properties: The properties of the surficial material are obtained from Ref 4 and summarized as follows:

$\gamma = 100$ pcf
$c' = 0$
$\phi' = 25°$

Calculations:

1) Dry Slope

$$F.S. = \frac{\tan\phi'}{\tan\beta} = \frac{\tan 25}{\tan 26} = 0.96$$

2) Perched Water Table leading to Seepage emerging from slope:

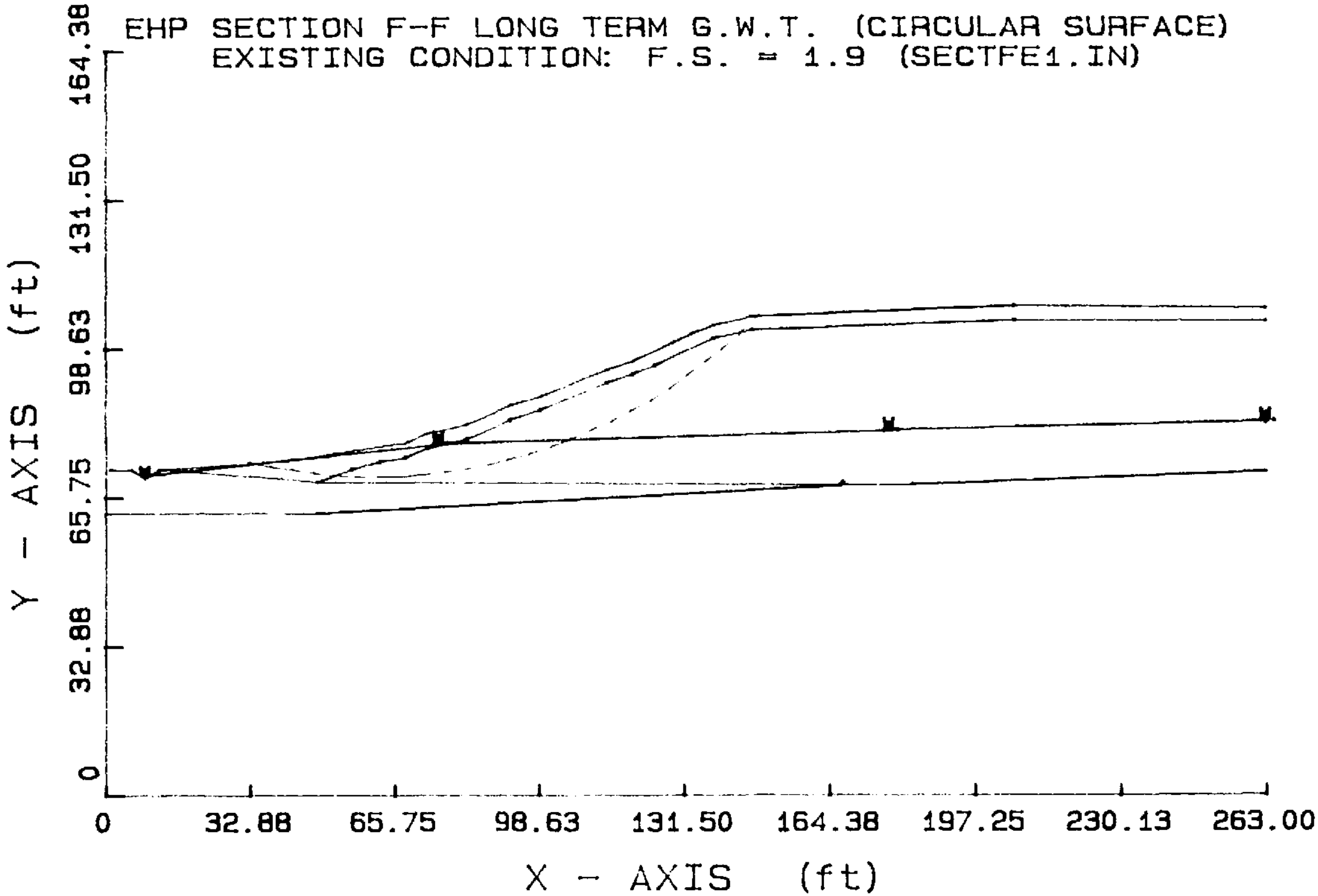
Assume seepage angle, θ, is 5° from the horizontal

According to Ref. 3

$$r_u = \frac{\gamma_w}{\gamma}\frac{1}{(1+\tan\beta\tan\theta)}$$

$$= \frac{62.4}{100}\left(\frac{1}{1+\tan 26\tan 5}\right) = 0.60$$

Section F-F' - Existing Conditions
Circular - Long-Term and Perched Water Tables



EHP SECTION F-F LONG TERM G.W.T. (CIRCULAR SURFACE)
EXISTING CONDITION: F.S. = 1.9 (SECTFE1.IN)
164.38
131.50
98.63
65.75
32.88
0
Y - AXIS (ft)
0
32.88
65.75
98.63
131.50
164.38
197.25
230.13
263.00
X - AXIS (ft)

1/9

2/9

** PCSTABL5M **

by
Purdue University

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

Run Date: 5/11/92
Time of Run:
Run By: DOKL
Input Data Filename: SECTFE1.IN
Output Filename: SECTFE1.OUT
Plotted Output Filename: SECTFE1.PLT

PROBLEM DESCRIPTION ISRT: SECTION F-F, EXISTING SLOPE FILE S
ECTFE1.IN

BOUNDARY COORDINATES

16 Top Boundaries
37 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	1.00	72.00	6.00	72.00	3
2	6.00	72.00	9.00	70.00	3
3	9.00	70.00	12.00	72.00	3
4	12.00	72.00	41.00	74.00	1
5	41.00	74.00	68.00	78.00	1
6	68.00	78.00	73.00	80.00	1
7	73.00	80.00	82.00	82.00	1
8	82.00	82.00	92.00	86.00	1
9	92.00	86.00	99.00	88.00	1
10	99.00	88.00	114.00	94.00	1
11	114.00	94.00	120.00	96.00	1
12	120.00	96.00	129.00	100.00	1
13	129.00	100.00	133.00	102.00	1
14	133.00	102.00	138.00	104.00	1
15	138.00	104.00	147.00	105.90	1
16	147.00	105.90	206.00	108.00	1
17	206.00	108.00	263.00	107.50	1
18	12.00	72.00	48.00	69.00	3
19	48.00	69.00	56.00	72.00	2
20	56.00	72.00	62.00	73.60	2
21	62.00	73.60	68.00	74.50	2
22	68.00	74.50	73.00	76.50	2
23	73.00	76.50	82.00	78.50	2
24	82.00	78.50	92.00	83.00	2
25	92.00	83.00	99.00	85.00	2
26	99.00	85.00	114.00	91.00	2
27	114.00	91.00	120.00	93.00	2
28	120.00	93.00	125.00	95.00	2
29	125.00	95.00	138.00	101.00	2
30	138.00	101.00	147.00	103.00	2

3/9

31	147.00	103.00	206.00	105.00	2
32	206.00	105.00	263.00	104.50	2
33	48.00	69.00	167.00	68.50	3
34	167.00	68.50	183.00	68.50	4
35	183.00	68.50	263.00	71.50	4
36	.00	62.00	48.00	62.00	4
37	48.00	62.00	167.00	68.50	4

1

ISOTROPIC SOIL PARAMETERS

4 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	90.0	100.0	.0	25.0	.00	.0	1
2	100.0	125.0	.0	34.0	.00	.0	1
3	120.0	120.0	.0	36.0	.00	.0	1
4	125.0	125.0	.0	37.0	.00	.0	1

1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 4 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	9.00	70.00
2	75.50	77.00
3	178.00	80.00
4	263.00	82.00

1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

400 Trial Surfaces Have Been Generated.

20 Surfaces Initiate From Each Of 20 Points Equally Spaced Along The Ground Surface Between X = 10.00 ft.
and X = 70.00 ft.

Each Surface Terminates Between X = 130.00 ft.
and X = 160.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = .00 ft.

5.00 ft. Line Segments Define Each Trial Failure Surface.

Restrictions Have Been Imposed Upon The Angle Of Initiation. The Angle Has Been Restricted Between The Angles Of -45.0 And -10.0 deg.

1

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 27 Coordinate Points

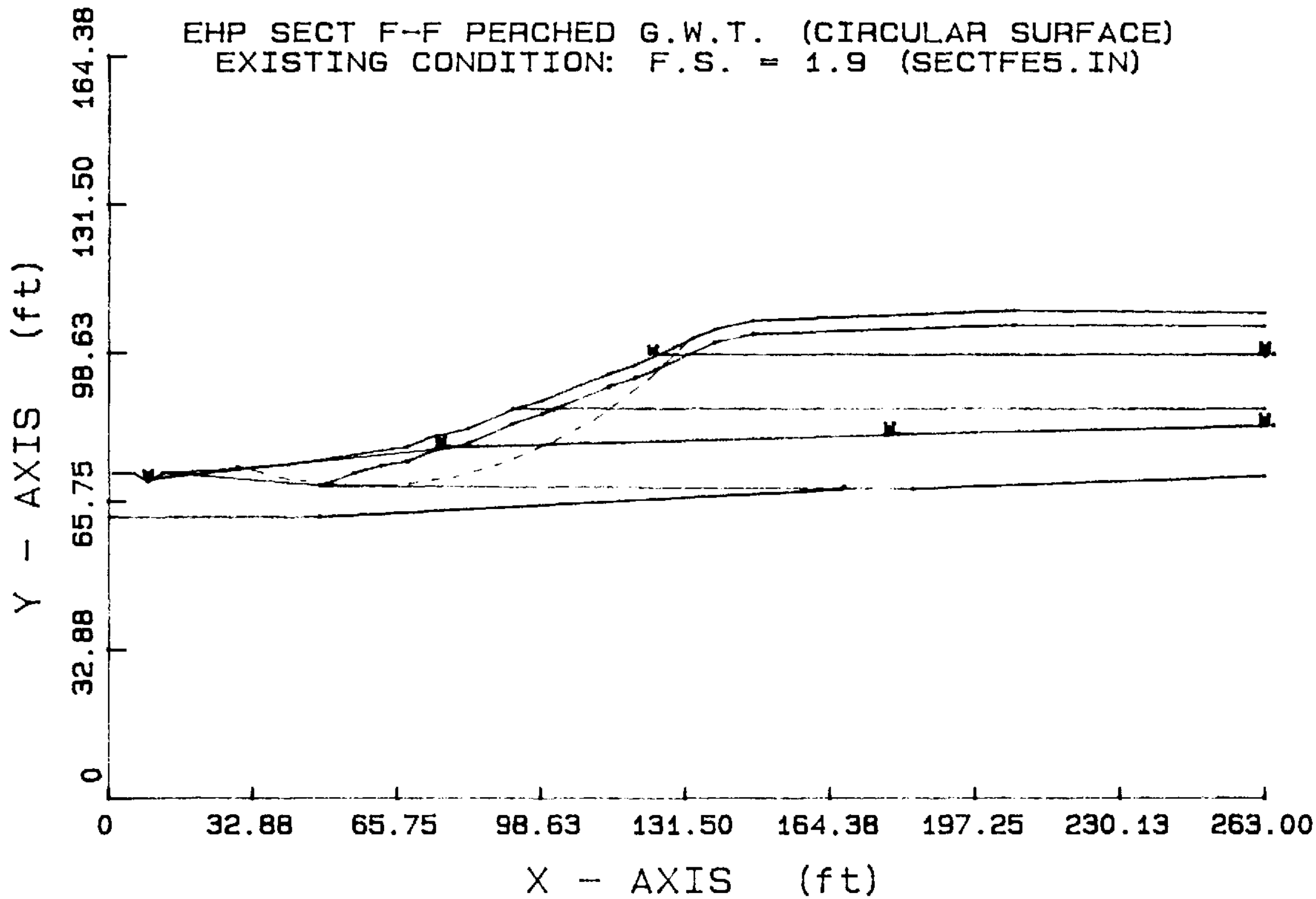
Point No.	X-Surf (ft)	Y-Surf (ft)
1	32.11	73.39
2	37.00	72.35
3	41.93	71.51
4	46.88	70.86
5	51.86	70.42
6	56.86	70.17
7	61.86	70.13
8	66.86	70.28
9	71.84	70.63
10	76.81	71.18
11	81.76	71.93
12	86.67	72.88
13	91.53	74.02
14	96.35	75.35
15	101.11	76.88
16	105.81	78.59
17	110.44	80.49
18	114.98	82.58
19	119.44	84.84
20	123.80	87.28
21	128.07	89.89
22	132.22	92.67
23	136.26	95.62
24	140.18	98.72
25	143.98	101.98
26	147.64	105.38
27	148.19	105.94

Circle Center At X = 60.5 ; Y = 195.3 and Radius, 125.2

*** 1.905 ***

Individual data on the 47 slices

Water Water Tie Tie Earthquake


EHP SECT F-F PERCHED G.W.T. (CIRCULAR SURFACE)
EXISTING CONDITION: F.S. = 1.9 (SECTFE5.IN)
Y - AXIS (ft)
0
32.88
65.75
98.63
131.50
164.38
X - AXIS (ft)
0
32.88
65.75
98.63
131.50
164.38
197.25
230.13
263.00

6/9

** PCSTABL5M **

by
Purdue University

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

Run Date: 5/11/92
Time of Run:
Run By: DOKL
Input Data Filename: SECTFE5.IN
Output Filename: SECTFE5.OUT
Plotted Output Filename: SECTFE5.PLT

PROBLEM DESCRIPTION ISRT: SECTION F-F, EXISTING SLOPE FILE S
ECTFE5.IN

BOUNDARY COORDINATES

17 Top Boundaries
40 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	1.00	72.00	6.00	72.00	5
2	6.00	72.00	9.00	70.00	5
3	9.00	70.00	12.00	72.00	5
4	12.00	72.00	41.00	74.00	1
5	41.00	74.00	68.00	78.00	1
6	68.00	78.00	73.00	80.00	1
7	73.00	80.00	82.00	82.00	1
8	82.00	82.00	92.00	86.00	1
9	92.00	86.00	99.00	88.00	2
10	99.00	88.00	114.00	94.00	2
11	114.00	94.00	120.00	96.00	2
12	120.00	96.00	129.00	100.00	2
13	129.00	100.00	133.00	102.00	2
14	133.00	102.00	138.00	104.00	2
15	138.00	104.00	147.00	105.90	2
16	147.00	105.90	206.00	108.00	2
17	206.00	108.00	263.00	107.50	2
18	92.00	86.00	101.50	86.00	1
19	12.00	72.00	48.00	69.00	5
20	48.00	69.00	56.00	72.00	3
21	56.00	72.00	62.00	73.60	3
22	62.00	73.60	68.00	74.50	3
23	68.00	74.50	73.00	76.50	3
24	73.00	76.50	82.00	78.50	3
25	82.00	78.50	92.00	83.00	3
26	92.00	83.00	99.00	85.00	3
27	99.00	85.00	101.50	86.00	3
28	101.50	86.00	114.00	91.00	4
29	114.00	91.00	120.00	93.00	4
30	120.00	93.00	125.00	95.00	4

31	125.00	95.00	138.00	101.00	4
32	138.00	101.00	147.00	103.00	4
33	147.00	103.00	206.00	105.00	4
34	206.00	105.00	263.00	104.50	4
35	101.50	86.00	263.00	86.00	3
36	48.00	69.00	167.00	68.50	5
37	167.00	68.50	183.00	68.50	6
38	183.00	68.50	263.00	71.50	6
39	.00	62.00	48.00	62.00	6
40	48.00	62.00	167.00	68.50	6

1

ISOTROPIC SOIL PARAMETERS

6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	90.0	100.0	.0	25.0	.00	.0	1
2	90.0	100.0	.0	25.0	.00	.0	2
3	100.0	125.0	.0	34.0	.00	.0	1
4	100.0	125.0	.0	34.0	.00	.0	2
5	120.0	120.0	.0	36.0	.00	.0	1
6	125.0	125.0	.0	37.0	.00	.0	1

1

2 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 4 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	9.00	70.00
2	75.50	77.00
3	178.00	80.00
4	263.00	82.00

Piezometric Surface No. 2 Specified by 2 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	124.00	97.50
2	263.00	97.50

1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

8/9

400 Trial Surfaces Have Been Generated.

20 Surfaces Initiate From Each Of 20 Points Equally Spaced
Along The Ground Surface Between X = 10.00 ft.
and X = 70.00 ft.

Each Surface Terminates Between X = 130.00 ft.
and X = 160.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is Y = .00 ft.

5.00 ft. Line Segments Define Each Trial Failure Surface.

Restrictions Have Been Imposed Upon The Angle Of Initiation.
The Angle Has Been Restricted Between The Angles Of -45.0
And -10.0 deg.

1

Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	28.95	73.17
2	33.78	71.88
3	38.67	70.82
4	43.60	70.01
5	48.57	69.44
6	53.56	69.11
7	58.55	69.03
8	63.55	69.20
9	68.54	69.61
10	73.49	70.26
11	78.41	71.16
12	83.28	72.30
13	88.09	73.68
14	92.82	75.29
15	97.47	77.13
16	102.02	79.20
17	106.47	81.48
18	110.79	83.99
19	114.99	86.70
20	119.06	89.62
21	122.97	92.73
22	126.73	96.03
23	130.31	99.51
24	132.32	101.66

9/9

Circle Center At X = 57.7 ; Y = 170.7 and Radius, 101.7

*** 1.911 ***

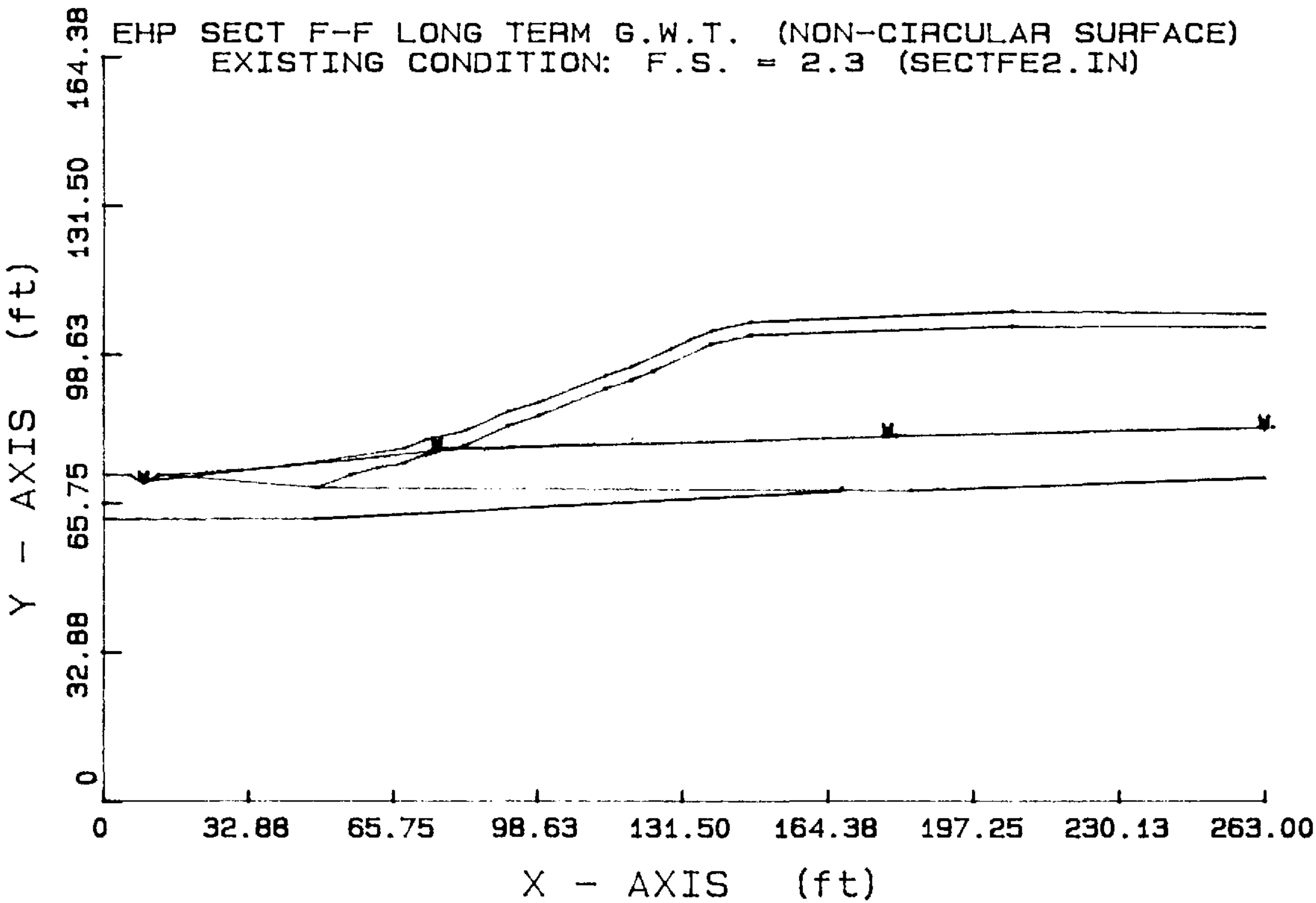
Individual data on the 45 slices

Slice No.	Width Ft(m)	Weight Lbs(kg)	Water Force Top Lbs(kg)	Water Force Bot Lbs(kg)	Tie Force Norm Lbs(kg)	Tie Force Tan Lbs(kg)	Earthquake Force Hor Lbs(kg)	Earthquake Force Ver Lbs(kg)	Surcharge Load Lbs(kg)
1	2.9	124.4	.0	.0	.0	.0	.0	.0	.0
2	2.0	236.2	.0	46.2	.0	.0	.0	.0	.0
3	4.9	1095.2	.0	470.8	.0	.0	.0	.0	.0
4	2.3	752.3	.0	384.3	.0	.0	.0	.0	.0
5	2.6	1013.5	.0	536.6	.0	.0	.0	.0	.0
6	5.0	2455.4	.0	1297.2	.0	.0	.0	.0	.0
7	.5	288.9	.0	152.0	.0	.0	.0	.0	.0
8	4.5	2868.1	.0	1446.7	.0	.0	.0	.0	.0
9	2.4	1817.5	.0	868.7	.0	.0	.0	.0	.0
10	2.6	2055.1	.0	956.0	.0	.0	.0	.0	.0
11	3.4	2973.1	.0	1349.4	.0	.0	.0	.0	.0
12	1.6	1401.4	.0	625.3	.0	.0	.0	.0	.0
13	4.4	4141.9	.0	1826.5	.0	.0	.0	.0	.0
14	.5	512.9	.0	221.7	.0	.0	.0	.0	.0
15	4.5	4627.4	.0	1843.9	.0	.0	.0	.0	.0
16	.5	544.7	.0	201.2	.0	.0	.0	.0	.0
17	1.5	1705.4	.0	625.2	.0	.0	.0	.0	.0
	.5	529.7	.0	191.4	.0	.0	.0	.0	.0
	2.9	3250.8	.0	1134.2	.0	.0	.0	.0	.0
20	3.6	3968.8	.0	1277.3	.0	.0	.0	.0	.0
21	1.3	1410.2	.0	414.5	.0	.0	.0	.0	.0
22	4.8	5398.0	.0	1343.9	.0	.0	.0	.0	.0
23	3.9	4436.2	.0	795.0	.0	.0	.0	.0	.0
24	.8	923.8	605.7	126.8	.0	.0	.0	.0	.0
25	4.6	5030.8	3198.4	426.4	.0	.0	.0	.0	.0
26	1.2	1244.2	767.7	21.4	.0	.0	.0	.0	.0
27	.3	323.0	198.2	.0	.0	.0	.0	.0	.0
28	2.5	2514.7	1512.2	.0	.0	.0	.0	.0	.0
29	.5	524.1	294.1	.0	.0	.0	.0	.0	.0
30	4.4	4460.1	2211.7	.0	.0	.0	.0	.0	.0
31	4.3	4254.3	1642.7	.0	.0	.0	.0	.0	.0
32	3.1	2938.2	870.7	.0	.0	.0	.0	.0	.0
33	.1	82.8	21.3	76.8	.0	.0	.0	.0	.0
34	1.0	893.5	218.1	821.7	.0	.0	.0	.0	.0
35	4.1	3172.7	665.6	2914.4	.0	.0	.0	.0	.0
36	.9	619.5	102.9	565.0	.0	.0	.0	.0	.0
37	3.0	1669.5	170.3	1408.9	.0	.0	.0	.0	.0
38	1.0	480.7	.0	369.7	.0	.0	.0	.0	.0
39	1.0	405.7	.0	284.6	.0	.0	.0	.0	.0
40	1.2	398.0	.0	239.4	.0	.0	.0	.0	.0
41	.6	165.0	.0	79.9	.0	.0	.0	.0	.0
42	1.5	360.4	.0	96.8	.0	.0	.0	.0	.0
43	.8	134.2	.0	.0	.0	.0	.0	.0	.0
44	1.3	172.0	.0	.0	.0	.0	.0	.0	.0
45	2.0	103.6	.0	.0	.0	.0	.0	.0	.0

1

Y A X I S F T

Section F-F' - Existing Conditions
Non-Circular - Long-Term Water Table


EHP SECT F-F LONG TERM G.W.T. (NON-CIRCULAR SURFACE)
EXISTING CONDITION: F.S. = 2.3 (SECTFE2.IN)
Y - AXIS (ft)
164.38
131.50
98.63
65.75
32.88
0
X - AXIS (ft)
0
32.88
65.75
98.63
131.50
164.38
197.25
230.13
263.00

2/3

** PCSTABL5M **

by
Purdue University

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

Run Date: 5/11/92
Time of Run:
Run By: DOKL
Input Data Filename: SECTFE2.IN
Output Filename: SECTFE2.OUT
Plotted Output Filename: SECTFE2.PLT

PROBLEM DESCRIPTION ISRT: SECTION F-F, EXISTING SLOPE FILE S
ECTFE2.IN

BOUNDARY COORDINATES

16 Top Boundaries
37 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	1.00	72.00	6.00	72.00	3
2	6.00	72.00	9.00	70.00	3
3	9.00	70.00	12.00	72.00	3
4	12.00	72.00	41.00	74.00	1
5	41.00	74.00	68.00	78.00	1
6	68.00	78.00	73.00	80.00	1
7	73.00	80.00	82.00	82.00	1
8	82.00	82.00	92.00	86.00	1
9	92.00	86.00	99.00	88.00	1
10	99.00	88.00	114.00	94.00	1
11	114.00	94.00	120.00	96.00	1
12	120.00	96.00	129.00	100.00	1
13	129.00	100.00	133.00	102.00	1
14	133.00	102.00	138.00	104.00	1
15	138.00	104.00	147.00	105.90	1
16	147.00	105.90	206.00	108.00	1
17	206.00	108.00	263.00	107.50	1
18	12.00	72.00	48.00	69.00	3
19	48.00	69.00	56.00	72.00	2
20	56.00	72.00	62.00	73.60	2
21	62.00	73.60	68.00	74.50	2
22	68.00	74.50	73.00	76.50	2
23	73.00	76.50	82.00	78.50	2
24	82.00	78.50	92.00	83.00	2
25	92.00	83.00	99.00	85.00	2
26	99.00	85.00	114.00	91.00	2
27	114.00	91.00	120.00	93.00	2
28	120.00	93.00	125.00	95.00	2
29	125.00	95.00	138.00	101.00	2
30	138.00	101.00	147.00	103.00	2

3/3

31	147.00	103.00	206.00	105.00	2
32	206.00	105.00	263.00	104.50	2
33	48.00	69.00	167.00	68.50	3
34	167.00	68.50	183.00	68.50	4
35	183.00	68.50	263.00	71.50	4
36	.00	62.00	48.00	62.00	4
37	48.00	62.00	167.00	68.50	4

1

ISOTROPIC SOIL PARAMETERS

4 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	90.0	100.0	.0	25.0	.00	.0	1
2	100.0	125.0	.0	34.0	.00	.0	1
3	120.0	120.0	.0	36.0	.00	.0	1
4	125.0	125.0	.0	37.0	.00	.0	1

1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 4 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	9.00	70.00
2	75.50	77.00
3	178.00	80.00
4	263.00	82.00

1

Trial Failure Surface Specified By 3 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	41.00	74.00
2	120.00	80.00
3	147.00	105.90

Spencer's Theta (deg)	FOS (Moment) (Equil.)	FOS (Force) (Equil.)
7.50	2.624	2.139
11.25	2.571	2.190
29.78	1.661	2.476
19.13	2.376	2.302

16.76	2.451	2.267
22.06	2.257	2.347
19.73	2.354	2.311
19.96	2.346	2.315
20.74	2.315	2.327
20.52	2.323	2.323

Factor Of Safety For The Preceding Specified Surface = 2.323
Spencer's Theta = 20.52

Factor Of Safety Is Calculated By Spencer's Method of Slices

*** Line of Thrust ***

Slice No.	X Coord.	Y Coord.	L/H	Side Force (lbs)
1	62.55	78.85	2.067	207.
2	68.00	79.47	1.756	320.
3	72.79	79.96	1.013	468.
4	73.00	79.93	.979	484.
5	75.03	79.76	.822	639.
6	75.50	79.75	.797	677.
7	82.00	80.23	.637	1297.
8	83.63	80.41	.586	1487.
9	92.00	81.47	.443	2798.
10	99.00	82.50	.427	4255.
11	114.00	84.94	.373	8529.
12	120.00	85.91	.369	10706.
13	125.00	89.82	.374	7342.
14	129.00	93.03	.386	5085.
15	133.00	96.17	.388	3220.
16	138.00	100.02	.408	1411.
17	143.07	103.73	.543	313.
18	147.00	288.81	.000	0.

1

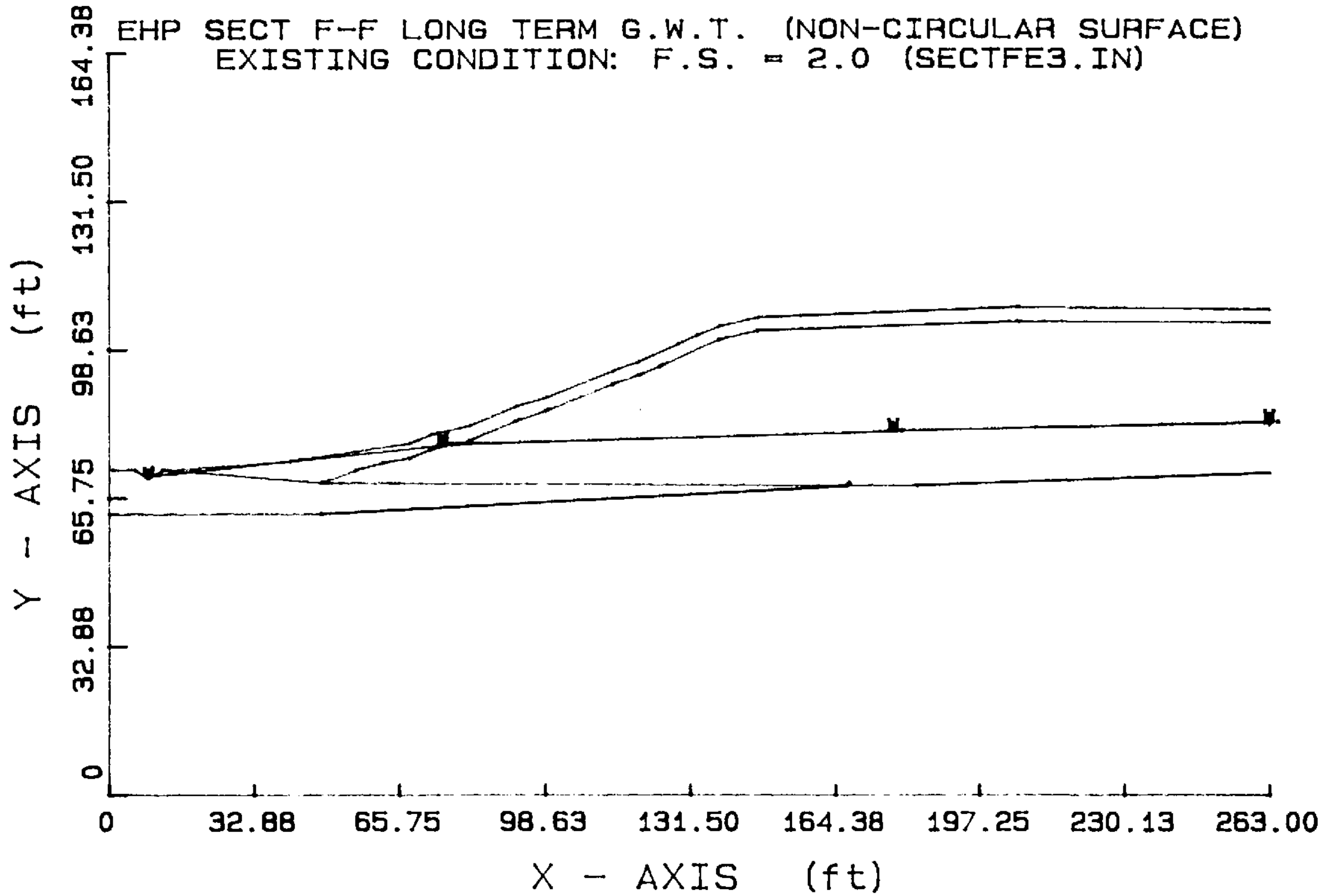
```
           Y            A     X     I     S           F     T

            .00     32.88    65.75     98.63    131.50    164.38

X        .00 +---------+--------*+-*-------+---------+---------+
            -                     *
            -                    **
            -
            -
            -
            -
      32.88 +
            -                      *
            -
            -                  * *
            -                     *
            -                     *
A      65.75 +                      **
            -                      **
            -                      W
            -                       **
            -
            -                        **
X      98.63 +                        **
```

5/3

```
            -
            -
            -                           **
            -                       S   **
            -                            *
I    131.50 +                             **
            -                              **
            -
            -                              **
            -
            -
S    164.38 +                    *
            -
            -                       W
            -                    *
            -
            -
     197.25 +
            -
            -                               **
            -
            -
            -
F    230.13 +
            -
            -
            -
            -
            -
T    263.00 +                     *  W      **
```


EHP SECT F-F LONG TERM G.W.T. (NON-CIRCULAR SURFACE)
EXISTING CONDITION: F.S. = 2.0 (SECTFE3.IN)
164.38
131.50
98.63
65.75
32.88
0
Y - AXIS (ft)
0
32.88
65.75
98.63
131.50
164.38
197.25
230.13
263.00
X - AXIS (ft)

7/3

** PCSTABL5M **

by
Purdue University

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

Run Date: 5/11/92
Time of Run:
Run By: DOKL
Input Data Filename: SECTFE3.IN
Output Filename: SECTFE3.OUT
Plotted Output Filename: SECTFE3.PLT

PROBLEM DESCRIPTION ISRT: SECTION F-F, EXISTING SLOPE FILE S
ECTFE3.IN

BOUNDARY COORDINATES

16 Top Boundaries
37 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	1.00	72.00	6.00	72.00	3
2	6.00	72.00	9.00	70.00	3
3	9.00	70.00	12.00	72.00	3
4	12.00	72.00	41.00	74.00	1
5	41.00	74.00	68.00	78.00	1
6	68.00	78.00	73.00	80.00	1
7	73.00	80.00	82.00	82.00	1
8	82.00	82.00	92.00	86.00	1
9	92.00	86.00	99.00	88.00	1
10	99.00	88.00	114.00	94.00	1
11	114.00	94.00	120.00	96.00	1
12	120.00	96.00	129.00	100.00	1
13	129.00	100.00	133.00	102.00	1
14	133.00	102.00	138.00	104.00	1
15	138.00	104.00	147.00	105.90	1
16	147.00	105.90	206.00	108.00	1
17	206.00	108.00	263.00	107.50	1
18	12.00	72.00	48.00	69.00	3
19	48.00	69.00	56.00	72.00	2
20	56.00	72.00	62.00	73.60	2
21	62.00	73.60	68.00	74.50	2
22	68.00	74.50	73.00	76.50	2
23	73.00	76.50	82.00	78.50	2
24	82.00	78.50	92.00	83.00	2
25	92.00	83.00	99.00	85.00	2
26	99.00	85.00	114.00	91.00	2
27	114.00	91.00	120.00	93.00	2
28	120.00	93.00	125.00	95.00	2
29	125.00	95.00	138.00	101.00	2
30	138.00	101.00	147.00	103.00	2

8/3

31	147.00	103.00	206.00	105.00	2
32	206.00	105.00	263.00	104.50	2
33	48.00	69.00	167.00	68.50	3
34	167.00	68.50	183.00	68.50	4
35	183.00	68.50	263.00	71.50	4
36	.00	62.00	48.00	62.00	4
37	48.00	62.00	167.00	68.50	4

1

ISOTROPIC SOIL PARAMETERS

4 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	90.0	100.0	.0	25.0	.00	.0	1
2	100.0	125.0	.0	34.0	.00	.0	1
3	120.0	120.0	.0	36.0	.00	.0	1
4	125.0	125.0	.0	37.0	.00	.0	1

1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 4 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	9.00	70.00
2	75.50	77.00
3	178.00	80.00
4	263.00	82.00

1

Trial Failure Surface Specified By 3 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	41.00	74.00
2	120.00	85.00
3	157.00	106.26

Spencer's Theta (deg)	FOS (Moment) (Equil.)	FOS (Force) (Equil.)
10.00	2.286	1.981
15.00	2.184	2.003
24.81	1.480	2.049
18.16	2.075	2.017

9/3

16.77	2.129	2.011
20.42	1.957	2.027
18.61	2.055	2.019
18.82	2.045	2.020
19.46	2.013	2.023
19.28	2.022	2.022

Factor Of Safety For The Preceding Specified Surface = 2.022
Spencer's Theta = 19.28

Factor Of Safety Is Calculated By Spencer's Method of Slices

*** Line of Thrust ***

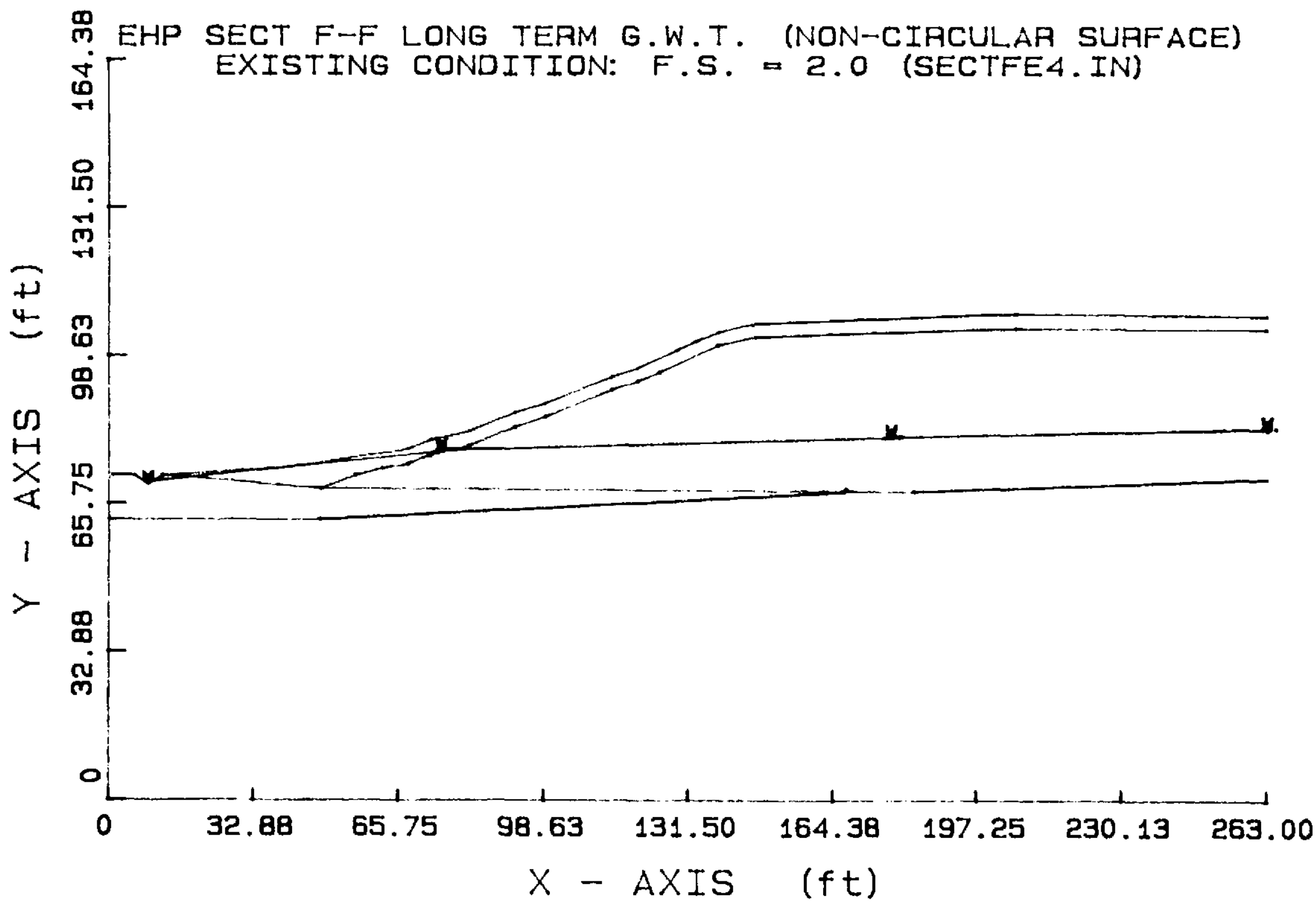
Slice No.	X Coord.	Y Coord.	L/H	Side Force (lbs)
1	68.00	80.60	11.815	28.
2	73.00	80.40	1.259	67.
3	82.00	81.55	.803	217.
4	85.89	82.23	.598	312.
5	92.00	82.77	.340	799.
6	99.00	84.05	.333	1552.
7	114.00	87.14	.303	3944.
8	120.00	88.36	.305	5222.
9	125.00	90.80	.283	4185.
10	129.00	92.77	.264	3403.
11	133.00	94.77	.241	2655.
12	138.00	97.38	.235	1776.
13	147.00	102.13	.301	560.
14	151.60	104.30	.394	208.
15	157.00	809.53	.000	0.

1

```
           Y            A     X     I     S            F     T

            .00     32.88     65.75     98.63    131.50    164.38

X        .00 +---------+--------*+-*--------+---------+---------+
             -                     *
             -                    **
             -
             -
             -
       32.88 +
             -                      *
             -
             -                  * *
             -                     *
             -                     *
A      65.75 +                      **
             -                      **
             -                      W
             -                       **
             -
             -                        **
X      98.63 +                         **
             -
             -
             -                           **
```


EHP SECT F-F LONG TERM G.W.T. (NON-CIRCULAR SURFACE)
EXISTING CONDITION: F.S. = 2.0 (SECTFE4.IN)
Y - AXIS (ft)
X - AXIS (ft)
0
32.88
65.75
98.63
131.50
164.38
197.25
230.13
263.00

11/13

** PCSTABL5M **

by
Purdue University

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

Run Date: 5/11/92
Time of Run:
Run By: DOKL
Input Data Filename: SECTFE4.IN
Output Filename: SECTFE4.OUT
Plotted Output Filename: SECTFE4.PLT

PROBLEM DESCRIPTION ISRT: SECTION F-F, EXISTING SLOPE FILE S
ECTFE3.IN

BOUNDARY COORDINATES

16 Top Boundaries
37 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	1.00	72.00	6.00	72.00	3
2	6.00	72.00	9.00	70.00	3
3	9.00	70.00	12.00	72.00	3
4	12.00	72.00	41.00	74.00	1
5	41.00	74.00	68.00	78.00	1
6	68.00	78.00	73.00	80.00	1
7	73.00	80.00	82.00	82.00	1
8	82.00	82.00	92.00	86.00	1
9	92.00	86.00	99.00	88.00	1
10	99.00	88.00	114.00	94.00	1
11	114.00	94.00	120.00	96.00	1
12	120.00	96.00	129.00	100.00	1
13	129.00	100.00	133.00	102.00	1
14	133.00	102.00	138.00	104.00	1
15	138.00	104.00	147.00	105.90	1
16	147.00	105.90	206.00	108.00	1
17	206.00	108.00	263.00	107.50	1
18	12.00	72.00	48.00	69.00	3
19	48.00	69.00	56.00	72.00	2
20	56.00	72.00	62.00	73.60	2
21	62.00	73.60	68.00	74.50	2
22	68.00	74.50	73.00	76.50	2
23	73.00	76.50	82.00	78.50	2
24	82.00	78.50	92.00	83.00	2
25	92.00	83.00	99.00	85.00	2
26	99.00	85.00	114.00	91.00	2
27	114.00	91.00	120.00	93.00	2
28	120.00	93.00	125.00	95.00	2
29	125.00	95.00	138.00	101.00	2
30	138.00	101.00	147.00	103.00	2

31	147.00	103.00	206.00	105.00	2
32	206.00	105.00	263.00	104.50	2
33	48.00	69.00	167.00	68.50	3
34	167.00	68.50	183.00	68.50	4
35	183.00	68.50	263.00	71.50	4
36	.00	62.00	48.00	62.00	4
37	48.00	62.00	167.00	68.50	4

1

ISOTROPIC SOIL PARAMETERS

4 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	90.0	100.0	.0	25.0	.00	.0	1
2	100.0	125.0	.0	34.0	.00	.0	1
3	120.0	120.0	.0	36.0	.00	.0	1
4	125.0	125.0	.0	37.0	.00	.0	1

1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 4 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	9.00	70.00
2	75.50	77.00
3	178.00	80.00
4	263.00	82.00

1

Trial Failure Surface Specified By 3 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	73.00	80.00
2	120.00	85.00
3	147.00	105.90

Spencer's Theta (deg)	FOS (Moment) (Equil.)	FOS (Force) (Equil.)
10.00	2.337	1.952
15.00	2.255	1.993
29.16	1.237	2.128
19.29	2.134	2.031

3/3

17.36	2.196	2.014
23.26	1.941	2.068
20.04	2.105	2.038
20.46	2.088	2.042
21.68	2.031	2.053
21.16	2.056	2.048
21.31	2.049	2.049

Factor Of Safety For The Preceding Specified Surface = 2.049
Spencer's Theta = 21.31

Factor Of Safety Is Calculated By Spencer's Method of Slices

*** Line of Thrust ***

Slice No.	X Coord.	Y Coord.	L/H	Side Force (lbs)
1	82.00	82.23	1.224	56.
2	89.15	83.28	.497	235.
3	92.00	83.41	.349	469.
4	99.00	84.67	.363	1229.
5	114.00	87.75	.352	3929.
6	120.00	88.91	.355	5444.
7	125.00	92.14	.350	3795.
8	129.00	94.75	.346	2675.
9	133.00	97.43	.342	1717.
10	138.00	100.91	.389	766.
11	141.74	103.41	.535	306.
12	147.00	364.78	.000	0.

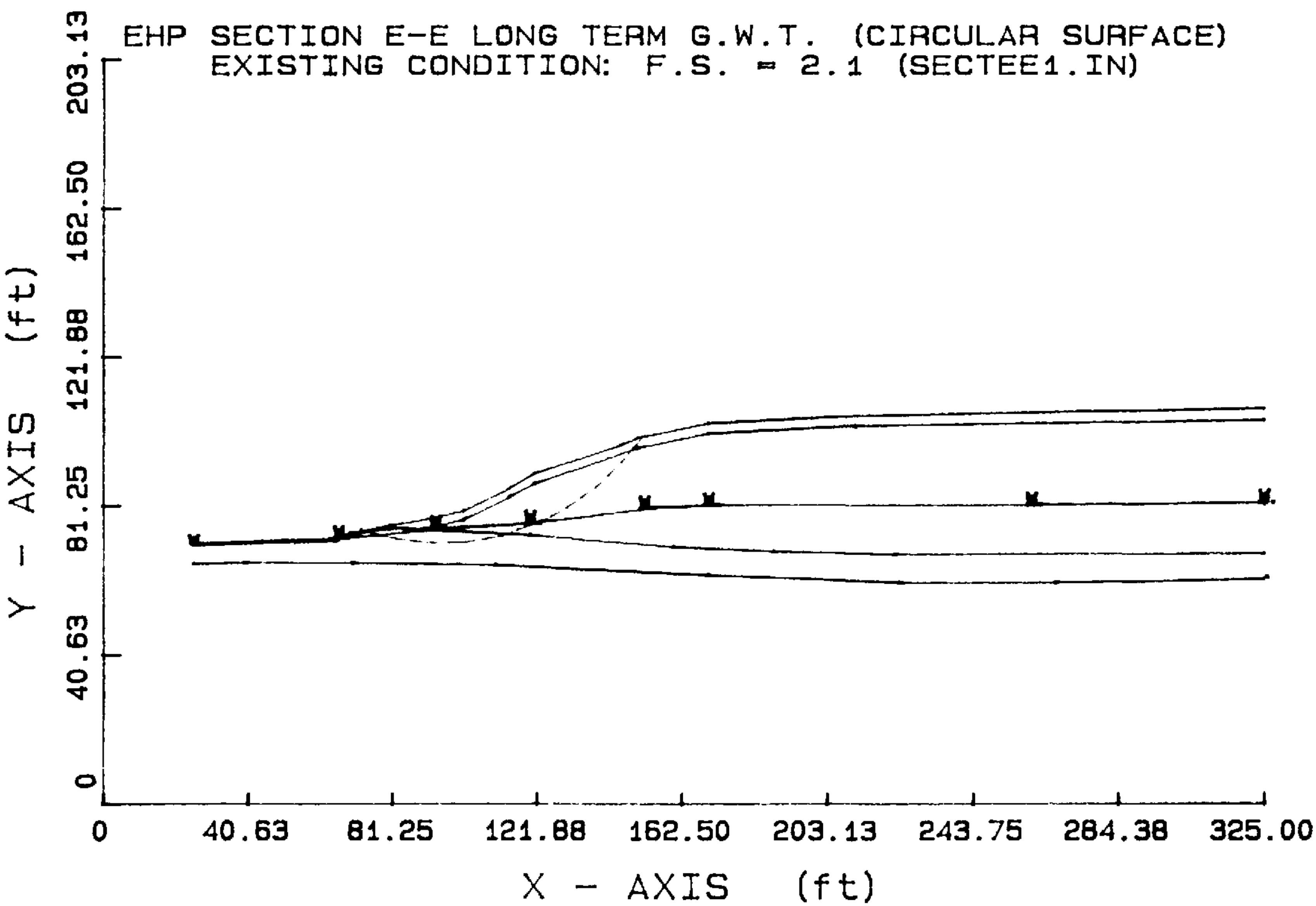
1

```
           Y            A     X     I     S            F     T

            .00     32.88     65.75     98.63    131.50    164.38

X       .00 +---------+--------*+-*-------+---------+---------+
            -                     *
            -                    **
            -
            -
            -
      32.88 +
            -                      *
            -
            -                  * *
            -                     *
            -                     *
A     65.75 +                      **
            -                      **
            -                      W
            -                       **
            -
            -                        **
X     98.63 +                         **
            -
            -
            -                           **
            -                         S **
            -                            *
```

Section E-E' - Existing Conditions
Circular - Long-Term Water Table


EHP SECTION E-E LONG TERM G.W.T. (CIRCULAR SURFACE)
EXISTING CONDITION: F.S. = 2.1 (SECTEE1.IN)
Y - AXIS (ft)
203.13
162.50
121.88
81.25
40.63
0
X - AXIS (ft)
40.63
81.25
121.88
162.50
203.13
243.75
284.38
325.00

2/4

** PCSTABL5M **

by
Purdue University

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

Run Date: 5/8/92
Time of Run:
Run By: DOKL
Input Data Filename: SECTEE1.IN
Output Filename: SECTEE1.OUT
Plotted Output Filename: SECTEE1.PLT

PROBLEM DESCRIPTION ISRT: SECTION E-E, EXISTING SLOPE FILE S
ECTEE1.IN

BOUNDARY COORDINATES

13 Top Boundaries
34 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	25.00	70.50	66.00	72.00	3
2	66.00	72.00	68.00	73.00	3
3	68.00	73.00	69.00	74.00	1
4	69.00	74.00	80.00	76.00	1
5	80.00	76.00	92.00	78.00	1
6	92.00	78.00	101.00	80.00	1
7	101.00	80.00	114.00	86.00	1
8	114.00	86.00	121.00	90.00	1
9	121.00	90.00	145.00	98.00	1
10	145.00	98.00	150.00	100.00	1
11	150.00	100.00	170.00	104.00	1
12	170.00	104.00	211.00	106.00	1
13	211.00	106.00	325.00	108.00	1
14	68.00	73.00	80.00	75.00	3
15	80.00	75.00	90.00	75.20	2
16	90.00	75.20	101.00	77.50	2
17	101.00	77.50	114.00	83.50	2
18	114.00	83.50	121.00	87.50	2
19	121.00	87.50	150.00	97.00	2
20	150.00	97.00	170.00	101.00	2
21	170.00	101.00	211.00	103.00	2
22	211.00	103.00	325.00	105.00	2
23	80.00	75.00	120.00	73.00	3
24	120.00	73.00	160.00	70.00	3
25	160.00	70.00	188.00	68.50	3
26	188.00	68.50	222.00	68.00	3
27	222.00	68.00	325.00	68.30	3
28	25.00	65.50	40.00	66.00	4
29	40.00	66.00	70.00	66.00	4
30	70.00	66.00	110.00	65.00	4

3/4

31	110.00	65.00	170.00	62.00	4
32	170.00	62.00	223.00	60.30	4
33	223.00	60.30	267.00	60.00	4
34	267.00	60.00	325.00	61.50	4

1

ISOTROPIC SOIL PARAMETERS

4 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	90.0	100.0	.0	25.0	.00	.0	1
2	100.0	125.0	.0	34.0	.00	.0	1
3	120.0	120.0	.0	36.0	.00	.0	1
4	125.0	125.0	.0	37.0	.00	.0	1

1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 8 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	25.00	70.20
2	66.00	71.80
3	93.00	74.50
4	120.00	76.00
5	152.00	80.00
6	170.00	81.00
7	260.00	81.00
8	325.00	81.60

1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

400 Trial Surfaces Have Been Generated.

20 Surfaces Initiate From Each Of 20 Points Equally Spaced Along The Ground Surface Between X = 65.00 ft.
and X = 110.00 ft.

Each Surface Terminates Between X = 150.00 ft.
and X = 210.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = .00 ft.

5.00 ft. Line Segments Define Each Trial Failure Surface.

Restrictions Have Been Imposed Upon The Angle Of Initiation.
The Angle Has Been Restricted Between The Angles Of -45.0
And -15.0 deg.

1

Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 19 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	72.11	74.56
2	76.91	73.17
3	81.79	72.11
4	86.75	71.41
5	91.73	71.07
6	96.73	71.08
7	101.72	71.44
8	106.67	72.16
9	111.55	73.24
10	116.35	74.65
11	121.03	76.41
12	125.57	78.49
13	129.96	80.90
14	134.16	83.61
15	138.16	86.61
16	141.93	89.89
17	145.46	93.43
18	148.73	97.21
19	150.95	100.19

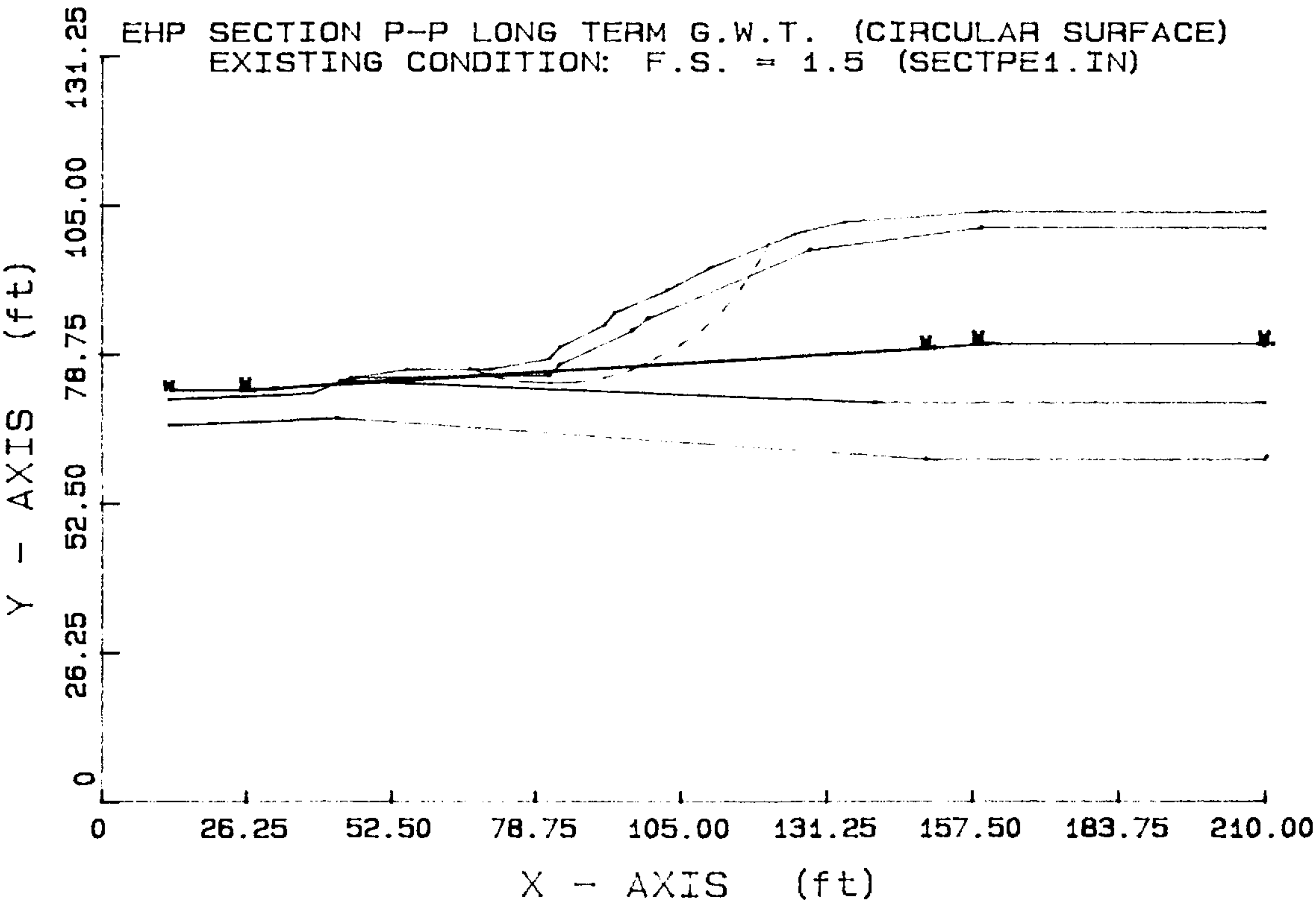
Circle Center At X = 94.1 ; Y = 141.1 and Radius, 70.1

*** 2.110 ***

Individual data on the 32 slices

Slice No.	Width Ft(m)	Weight Lbs(kg)	Water Force Top Lbs(kg)	Water Force Bot Lbs(kg)	Tie Force Norm Lbs(kg)	Tie Force Tan Lbs(kg)	Earthquake Force Hor Lbs(kg)	Earthquake Force Ver Lbs(kg)	Surcharge Load Lbs(kg)
1	1.9	78.7	.0	.0	.0	.0	.0	.0	.0
2	2.9	468.7	.0	.0	.0	.0	.0	.0	.0
3	.9	231.7	.0	.0	.0	.0	.0	.0	.0
4	2.2	748.7	.0	49.2	.0	.0	.0	.0	.0

Sections P-P' and V-V' - Existing Conditions
Circular - Long-Term Water Table



EHP SECTION P-P LONG TERM G.W.T. (CIRCULAR SURFACE)
EXISTING CONDITION: F.S. = 1.5 (SECTPE1.IN)
Y - AXIS (ft)
X - AXIS (ft)
0
26.25
52.50
78.75
105.00
131.25
183.75
157.50
210.00

** PCSTABL5M **

by
Purdue University

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

Run Date: 5/8/92
Time of Run:
Run By: DOKL
Input Data Filename: SECTPE1.IN
Output Filename: SECTPE1.OUT
Plotted Output Filename: SECTPE1.PLT

PROBLEM DESCRIPTION ISRT: SECTION P-P, EXISTING SLOPE FILE S
ECTPE1.IN

BOUNDARY COORDINATES

15 Top Boundaries
27 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	12.00	71.00	38.00	72.00	3
2	38.00	72.00	43.00	74.00	3
3	43.00	74.00	45.00	74.50	2
4	45.00	74.50	55.00	76.00	1
5	55.00	76.00	70.00	76.00	1
6	70.00	76.00	81.00	78.00	1
7	81.00	78.00	83.00	80.00	1
8	83.00	80.00	91.00	84.00	1
9	91.00	84.00	93.00	86.00	1
10	93.00	86.00	102.50	90.00	1
11	102.50	90.00	110.00	94.00	1
12	110.00	94.00	125.50	100.00	1
13	125.50	100.00	134.50	102.00	1
14	134.50	102.00	159.00	104.00	1
15	159.00	104.00	210.00	104.00	1
16	45.00	74.50	81.00	75.00	2
17	81.00	75.00	83.00	77.00	2
18	83.00	77.00	96.00	83.00	2
19	96.00	83.00	99.00	85.00	2
20	99.00	85.00	128.00	97.20	2
21	128.00	97.20	159.00	101.00	2
22	159.00	101.00	210.00	101.00	2
23	43.00	74.00	140.00	70.00	3
24	140.00	70.00	210.00	70.00	3
25	12.00	66.20	42.50	67.50	4
26	42.50	67.50	149.00	60.20	4
27	149.00	60.20	210.00	60.20	4

ISOTROPIC SOIL PARAMETERS

4 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	90.0	100.0	.0	25.0	.00	.0	1
2	100.0	125.0	.0	31.0	.00	.0	1
3	120.0	120.0	.0	36.0	.00	.0	1
4	125.0	125.0	.0	37.0	.00	.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 5 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	12.00	72.00
2	26.00	72.00
3	149.00	79.20
4	158.50	80.00
5	210.00	80.00

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

400 Trial Surfaces Have Been Generated.

20 Surfaces Initiate From Each Of 20 Points Equally Spaced Along The Ground Surface Between X = 60.00 ft. and X = 100.00 ft.

Each Surface Terminates Between X = 120.00 ft. and X = 170.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = .00 ft.

5.00 ft. Line Segments Define Each Trial Failure Surface.

Restrictions Have Been Imposed Upon The Angle Of Initiation. The Angle Has Been Restricted Between The Angles Of -45.0 And -15.0 deg.

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 14 Coordinate Points

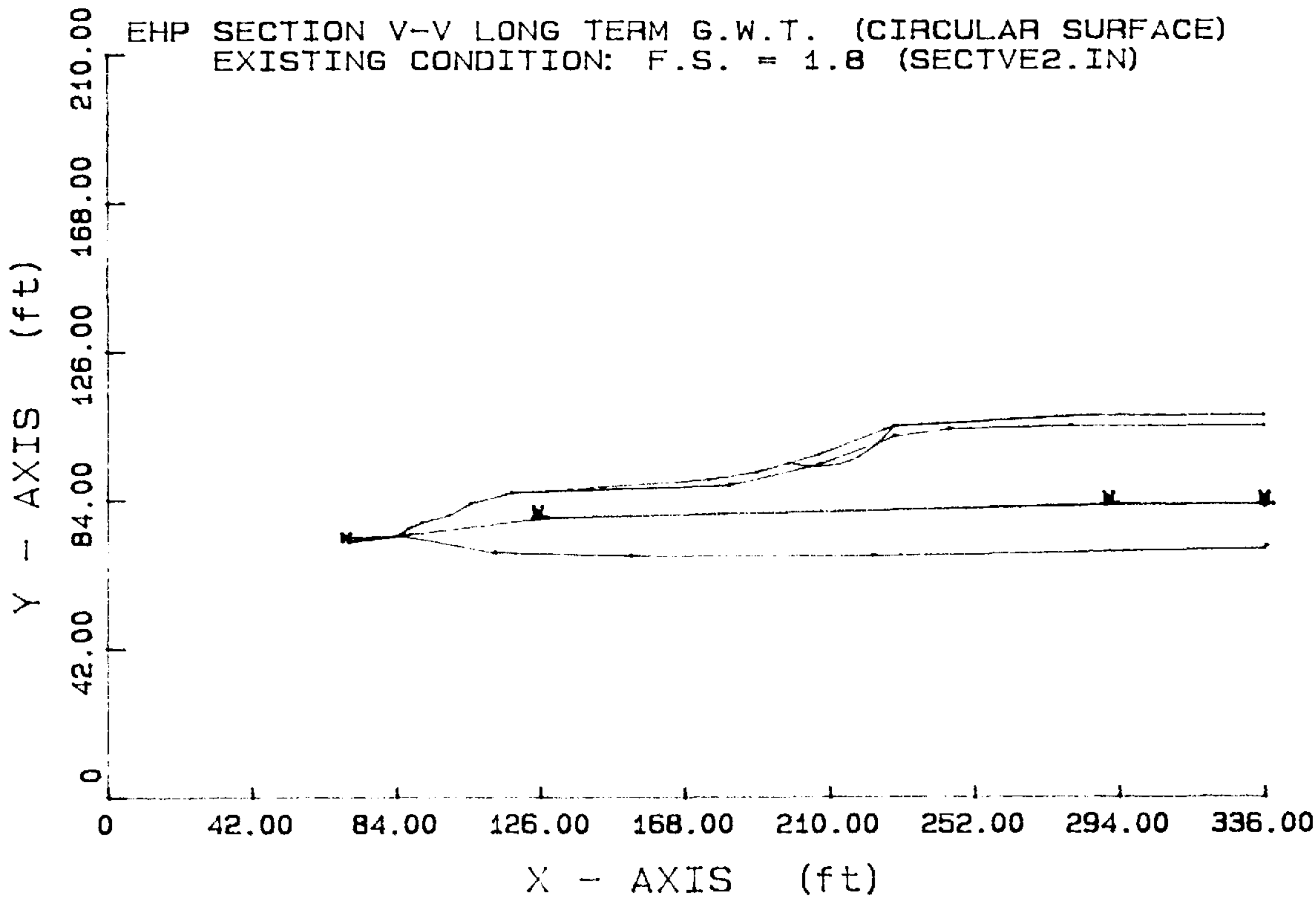
Point No.	X-Surf (ft)	Y-Surf (ft)
1	66.32	76.00
2	71.12	74.60
3	76.04	73.75
4	81.04	73.47
5	86.03	73.74
6	90.96	74.58
7	95.76	75.97
8	100.38	77.89
9	104.75	80.32
10	108.82	83.22
11	112.53	86.57
12	115.85	90.31
13	118.72	94.40
14	120.78	98.17

Circle Center At X = 81.1 ; Y = 117.7 and Radius, 44.2

*** 1.502 ***

Individual data on the 28 slices

Slice No.	Width Ft(m)	Weight Lbs(kg)	Water Force Top Lbs(kg)	Water Force Bot Lbs(kg)	Tie Force Norm Lbs(kg)	Tie Force Tan Lbs(kg)	Earthquake Force Hor Lbs(kg)	Earthquake Force Ver Lbs(kg)	Surcharge Load Lbs(kg)
1	3.7	177.8	.0	.0	.0	.0	.0	.0	.0
2	.3	26.8	.0	.0	.0	.0	.0	.0	.0
3	.7	92.6	.0	.0	.0	.0	.0	.0	.0
4	.1	16.1	.0	.1	.0	.0	.0	.0	.0
5	4.9	1206.8	.0	189.1	.0	.0	.0	.0	.0
6	.0	13.4	.0	2.9	.0	.0	.0	.0	.0
7	4.9	1983.3	.0	449.6	.0	.0	.0	.0	.0
8	.0	16.8	.0	4.0	.0	.0	.0	.0	.0
9	.2	94.3	.0	21.6	.0	.0	.0	.0	.0
10	1.8	1012.2	.0	193.8	.0	.0	.0	.0	.0
11	3.0	2190.4	.0	333.7	.0	.0	.0	.0	.0
12	4.9	4257.3	.0	466.0	.0	.0	.0	.0	.0
13	.0	39.5	.0	3.3	.0	.0	.0	.0	.0
14	2.0	1995.7	.0	127.3	.0	.0	.0	.0	.
15	2.8	2951.1	.0	77.5	.0	.0	.0	.0	.
16	.2	257.3	.0	1.2	.0	.0	.0	.0	.0
17	.1	89.5	.0	.1	.0	.0	.0	.0	.0
18	2.9	3154.6	.0	.0	.0	.0	.0	.0	.0
19	1.4	1496.7	.0	.0	.0	.0	.0	.0	.0


EHP SECTION V-V LONG TERM G.W.T. (CIRCULAR SURFACE)
EXISTING CONDITION: F.S. = 1.8 (SECTVE2.IN)
Y - AXIS (ft)
X - AXIS (ft)
0
42.00
84.00
126.00
168.00
210.00
252.00
294.00
336.00

818

** PCSTABL5M **

by
Purdue University

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

Run Date: 5/8/92
Time of Run:
Run By: DOKL
Input Data Filename: SECTVE2.IN
Output Filename: SECTVE2.OUT
Plotted Output Filename: SECTVE2.PLT

PROBLEM DESCRIPTION ISRT: SECTION V-V, EXISTING SLOPE FILE S
ECTVE2.IN

BOUNDARY COORDINATES

13 Top Boundaries
23 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	69.00	73.30	84.50	74.00	3
2	84.50	74.00	87.50	76.00	2
3	87.50	76.00	91.00	77.50	2
4	91.00	77.50	99.00	80.00	2
5	99.00	80.00	105.50	83.00	2
6	105.50	83.00	117.50	86.00	2
7	117.50	86.00	175.00	90.00	1
8	175.00	90.00	189.00	92.00	1
9	189.00	92.00	207.00	97.00	1
10	207.00	97.00	226.00	104.00	1
11	226.00	104.00	229.00	105.00	1
12	229.00	105.00	283.00	108.00	1
13	283.00	108.00	336.00	108.00	1
14	117.50	86.00	181.00	88.00	2
15	181.00	88.00	207.00	94.00	2
16	207.00	94.00	229.00	102.00	2
17	229.00	102.00	245.00	104.00	2
18	245.00	104.00	280.00	105.00	2
19	280.00	105.00	336.00	105.00	2
20	84.50	74.00	112.50	69.00	3
21	112.50	69.00	152.50	68.00	3
22	152.50	68.00	222.50	68.00	3
23	222.50	68.00	336.00	70.00	3

1

ISOTROPIC SOIL PARAMETERS

3 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	90.0	100.0	.0	25.0	.00	.0	1
2	100.0	125.0	.0	28.0	.00	.0	1
3	120.0	120.0	.0	36.0	.00	.0	1

1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 4 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	69.00	71.50
2	125.00	78.00
3	291.00	82.00
4	336.00	82.00

1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

400 Trial Surfaces Have Been Generated.

20 Surfaces Initiate From Each Of 20 Points Equally Spaced Along The Ground Surface Between X = 160.00 ft.
and X = 200.00 ft.

Each Surface Terminates Between X = 220.00 ft.
and X = 260.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = .00 ft.

3.00 ft. Line Segments Define Each Trial Failure Surface.

Restrictions Have Been Imposed Upon The Angle Of Initiation. The Angle Has Been Restricted Between The Angles Of -45.0 And -10.0 deg.

1

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	197.90	94.47
2	200.81	93.76
3	203.78	93.37
4	206.78	93.29
5	209.77	93.55
6	212.72	94.12
7	215.58	95.00
8	218.34	96.19
9	220.95	97.67
10	223.38	99.43
11	225.61	101.43
12	227.62	103.66
13	228.45	104.82

Circle Center At X = 205.9 ; Y = 121.1 and Radius, 27.8

*** 1.755 ***

Individual data on the 16 slices

Slice No.	Width Ft(m)	Weight Lbs(kg)	Water Force Top Lbs(kg)	Water Force Bot Lbs(kg)	Tie Force Norm Lbs(kg)	Tie Force Tan Lbs(kg)	Earthquake Force Hor Lbs(kg)	Earthquake Force Ver Lbs(kg)	Surcharge Load Lbs(kg)
1	2.9	199.5	.0	.0	.0	.0	.0	.0	.0
2	3.0	570.5	.0	.0	.0	.0	.0	.0	.0
3	.4	106.5	.0	.0	.0	.0	.0	.0	.0
4	2.6	764.0	.0	.0	.0	.0	.0	.0	.0
5	.2	73.1	.0	.0	.0	.0	.0	.0	.0
6	2.8	1048.2	.0	.0	.0	.0	.0	.0	.0
7	2.9	1304.4	.0	.0	.0	.0	.0	.0	.0
8	2.9	1366.8	.0	.0	.0	.0	.0	.0	.0
9	2.8	1312.2	.0	.0	.0	.0	.0	.0	.0
10	2.6	1152.6	.0	.0	.0	.0	.0	.0	.0
11	2.4	908.1	.0	.0	.0	.0	.0	.0	.0
12	1.0	301.6	.0	.0	.0	.0	.0	.0	.0
13	1.2	307.3	.0	.0	.0	.0	.0	.0	.0
14	.4	79.3	.0	.0	.0	.0	.0	.0	.0
15	1.6	219.5	.0	.0	.0	.0	.0	.0	.0
16	.8	32.6	.0	.0	.0	.0	.0	.0	.0

Failure Surface Specified By 10 Coordinate Points

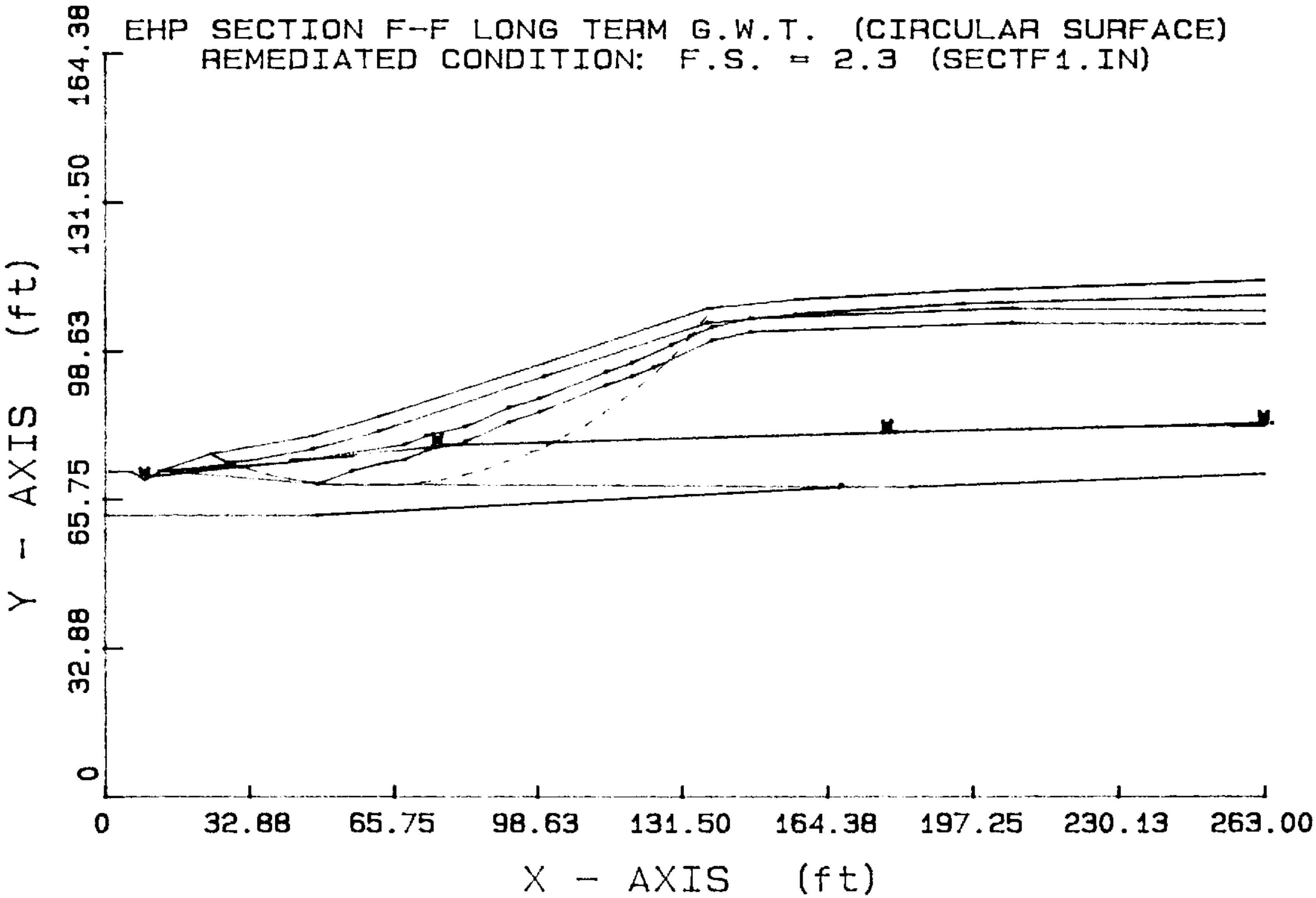
Point No.	X-Surf (ft)	Y-Surf (ft)
1	197.90	94.47
2	200.82	93.78
3	203.80	93.53

APPENDIX 12-C

Remediated Slope Stability Calculations

Section F-F' - Remediated Condition
Circular - Long-Term Water Table
Unit Weights of Fill and Hide Residue = 115 and 125 pcf

Unit Weight of Fill and Hide Residue = 125 pcf


EHP SECTION F-F LONG TERM G.W.T. (CIRCULAR SURFACE)
REMEDIATED CONDITION: F.S. = 2.3 (SECTF1.IN)
Y - AXIS (ft)
0
32.88
65.75
98.63
131.50
164.38
X - AXIS (ft)
0
32.88
65.75
98.63
131.50
164.38
197.25
230.13
263.00

5

** PCSTABL5M **

by
Purdue University

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

Run Date: 5/11/92
Time of Run:
Run By: DOKL
Input Data Filename: SECTF1.IN
Output Filename: SECTF1.OUT
Plotted Output Filename: SECTF1.PLT

PROBLEM DESCRIPTION ISRT: SECTION F-F, REMEDIATED SLOPE FILE
SECTF1.IN

BOUNDARY COORDINATES

11 Top Boundaries
54 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	1.00	72.00	6.00	72.00	5
2	6.00	72.00	9.00	70.00	5
3	9.00	70.00	12.00	72.00	5
4	12.00	72.00	24.00	76.00	1
5	24.00	76.00	47.00	80.00	1
6	47.00	80.00	62.00	84.00	1
7	62.00	84.00	100.00	96.00	1
8	100.00	96.00	137.00	108.00	1
9	137.00	108.00	157.00	110.00	1
10	157.00	110.00	195.00	112.00	1
11	195.00	112.00	263.00	114.30	1
12	12.00	72.00	22.00	72.50	3
13	22.00	72.50	24.00	73.00	2
14	24.00	73.00	47.00	77.00	2
15	47.00	77.00	62.00	81.00	2
16	62.00	81.00	100.00	93.00	2
17	100.00	93.00	137.00	105.00	2
18	137.00	105.00	157.00	107.00	2
19	157.00	107.00	195.00	109.00	2
20	195.00	109.00	263.00	111.00	2
21	22.00	72.50	41.00	74.00	3
22	41.00	74.00	68.00	78.00	3
23	68.00	78.00	73.00	80.00	3
24	73.00	80.00	82.00	82.00	3
25	82.00	82.00	92.00	86.00	3
26	92.00	86.00	99.00	88.00	3
27	99.00	88.00	114.00	94.00	3
28	114.00	94.00	120.00	96.00	3
29	120.00	96.00	129.00	100.00	3
30	129.00	100.00	133.00	102.00	3

31	133.00	102.00	138.00	104.00	3
32	138.00	104.00	147.00	105.90	3
33	147.00	105.90	206.00	108.00	3
34	206.00	108.00	263.00	107.50	3
35	12.00	72.00	48.00	69.00	5
36	48.00	69.00	56.00	72.00	4
37	56.00	72.00	62.00	73.60	4
38	62.00	73.60	68.00	74.50	4
39	68.00	74.50	73.00	76.50	4
40	73.00	76.50	82.00	78.50	4
41	82.00	78.50	92.00	83.00	4
42	92.00	83.00	99.00	85.00	4
43	99.00	85.00	114.00	91.00	4
44	114.00	91.00	120.00	93.00	4
45	120.00	93.00	125.00	95.00	4
46	125.00	95.00	138.00	101.00	4
47	138.00	101.00	147.00	103.00	4
48	147.00	103.00	206.00	105.00	4
49	206.00	105.00	263.00	104.50	4
50	48.00	69.00	167.00	68.50	5
51	167.00	68.50	183.00	68.50	6
52	183.00	68.50	263.00	71.50	6
53	.00	62.00	48.00	62.00	6
54	48.00	62.00	167.00	68.50	6

1

ISOTROPIC SOIL PARAMETERS

6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	120.0	120.0	.0	.0	.00	.0	1
2	125.0	125.0	.0	33.0	.00	.0	1
3	90.0	100.0	.0	25.0	.00	.0	1
4	100.0	125.0	.0	34.0	.00	.0	1
5	120.0	120.0	.0	36.0	.00	.0	1
6	125.0	125.0	.0	37.0	.00	.0	1

1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 4 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	9.00	70.00
2	75.50	77.00
3	178.00	80.00
4	263.00	82.00

1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

400 Trial Surfaces Have Been Generated.

20 Surfaces Initiate From Each Of 20 Points Equally Spaced Along The Ground Surface Between X = 10.00 ft. and X = 70.00 ft.

Each Surface Terminates Between X = 130.00 ft. and X = 160.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = .00 ft.

5.00 ft. Line Segments Define Each Trial Failure Surface.

Restrictions Have Been Imposed Upon The Angle Of Initiation. The Angle Has Been Restricted Between The Angles Of -45.0 And -20.0 deg.

1

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 27 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	22.63	75.54
2	27.32	73.81
3	32.10	72.32
4	36.94	71.08
5	41.84	70.08
6	46.78	69.32
7	51.75	68.82
8	56.75	68.57
9	61.75	68.57
10	66.74	68.83
11	71.72	69.33
12	76.66	70.09
13	81.56	71.09
14	86.40	72.34
15	91.17	73.84
16	95.86	75.57
17	100.46	77.54
18	104.95	79.73
19	109.32	82.15
20	113.57	84.79
21	117.68	87.64

515

22	121.64	90.69
23	125.44	93.94
24	129.07	97.38
25	132.52	100.99
26	135.79	104.78
27	138.41	108.14

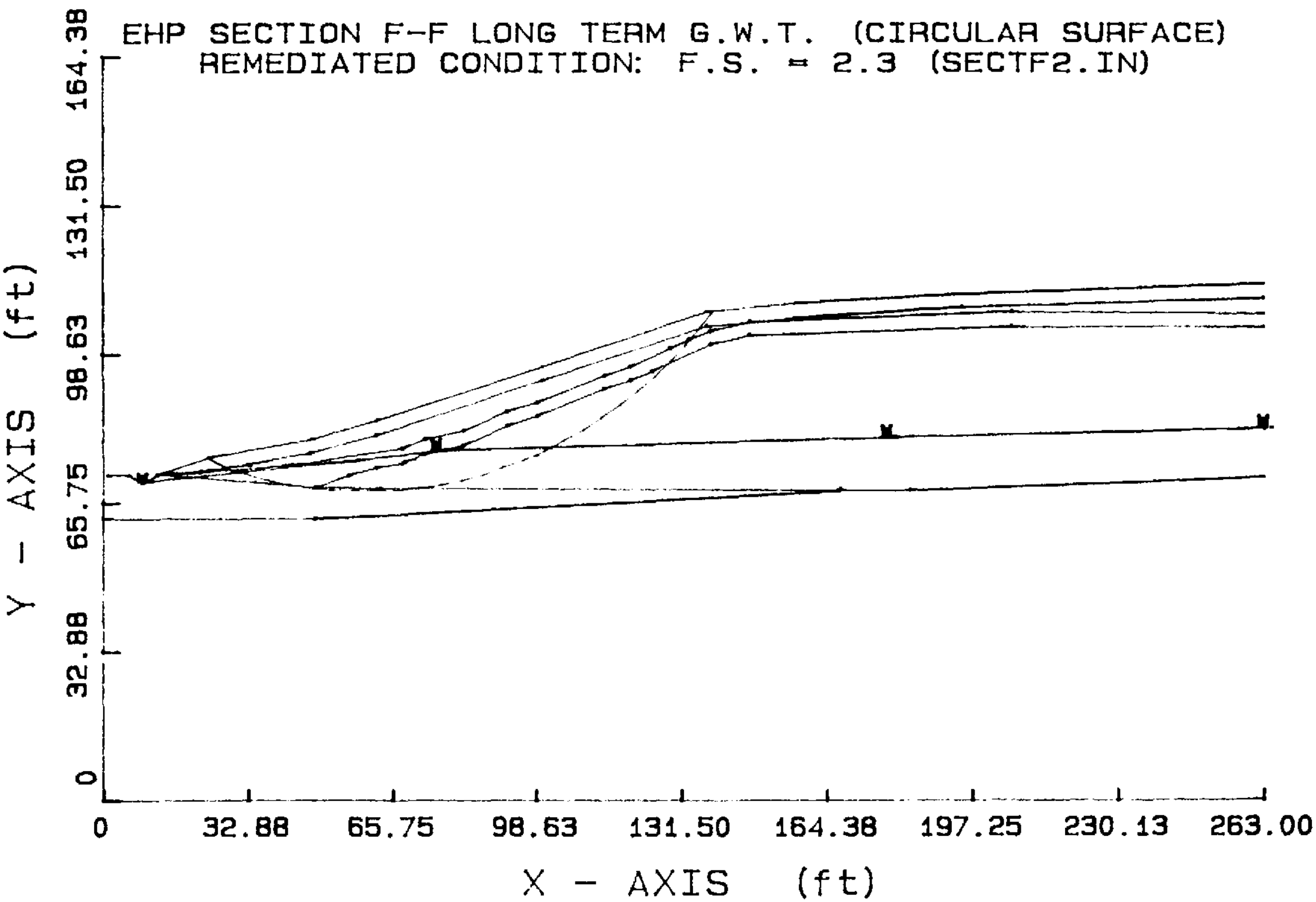
Circle Center At X = 59.2 ; Y = 167.6 and Radius, 99.0

*** 2.316 ***

Individual data on the 55 slices

Slice No.	Width Ft(m)	Weight Lbs(kg)	Water Force Top Lbs(kg)	Water Force Bot Lbs(kg)	Tie Force Norm Lbs(kg)	Tie Force Tan Lbs(kg)	Earthquake Force Hor Lbs(kg)	Earthquake Force Ver Lbs(kg)	Surcharge Load Lbs(kg)
1	1.4	78.8	.0	.0	.0	.0	.0	.0	.0
2	3.3	742.5	.0	.0	.0	.0	.0	.0	.0
3	.5	168.4	.0	.0	.0	.0	.0	.0	.0
4	1.8	746.2	.0	.0	.0	.0	.0	.0	.0
5	2.2	1164.1	.0	.0	.0	.0	.0	.0	.0
6	.3	148.5	.0	.9	.0	.0	.0	.0	.0
7	4.8	3381.0	.0	305.7	.0	.0	.0	.0	.0
8	4.1	3620.2	.0	641.4	.0	.0	.0	.0	.0
9	.8	827.9	.0	172.3	.0	.0	.0	.0	.0
10	4.9	5369.9	.0	1246.6	.0	.0	.0	.0	.0
11	.2	257.8	.0	64.2	.0	.0	.0	.0	.0
	1.4	1704.5	.0	428.8	.0	.0	.0	.0	.0
13	1.6	2085.2	.0	528.0	.0	.0	.0	.0	.0
14	1.7	2299.7	.0	582.3	.0	.0	.0	.0	.0
15	4.2	6342.7	.0	1585.5	.0	.0	.0	.0	.0
16	.7	1200.4	.0	297.5	.0	.0	.0	.0	.0
17	5.0	8548.2	.0	2084.9	.0	.0	.0	.0	.0
18	.3	454.0	.0	109.3	.0	.0	.0	.0	.0
19	4.7	8938.1	.0	2099.0	.0	.0	.0	.0	.0
20	.9	1792.7	.0	410.7	.0	.0	.0	.0	.0
21	.4	698.9	.0	158.8	.0	.0	.0	.0	.0
22	3.7	7585.1	.0	1683.8	.0	.0	.0	.0	.0
23	1.3	2691.8	.0	583.6	.0	.0	.0	.0	.0
24	2.0	4307.6	.0	910.4	.0	.0	.0	.0	.0
25	.5	1021.3	.0	211.8	.0	.0	.0	.0	.0
26	1.2	2507.3	.0	513.1	.0	.0	.0	.0	.0
27	4.9	10752.2	.0	2032.1	.0	.0	.0	.0	.0
28	.4	983.5	.0	172.4	.0	.0	.0	.0	.0
29	4.4	9740.0	.0	1552.5	.0	.0	.0	.0	.0
30	4.8	10456.2	.0	1340.8	.0	.0	.0	.0	.0
31	.8	1798.2	.0	192.3	.0	.0	.0	.0	.0
32	3.9	8232.7	.0	688.7	.0	.0	.0	.0	.0
33	3.1	6518.6	.0	298.5	.0	.0	.0	.0	.0
34	1.0	2032.0	.0	39.1	.0	.0	.0	.0	.0
35	.5	919.8	.0	8.8	.0	.0	.0	.0	.0
36	.4	848.2	.0	2.9	.0	.0	.0	.0	.0
37	4.1	7975.0	.0	.0	.0	.0	.0	.0	.0
38	4.4	8175.5	.0	.0	.0	.0	.0	.0	.0
39	4.2	7421.7	.0	.0	.0	.0	.0	.0	.0
	.4	718.2	.0	.0	.0	.0	.0	.0	.0
41	3.7	5869.5	.0	.0	.0	.0	.0	.0	.0
42	2.3	3423.0	.0	.0	.0	.0	.0	.0	.0
43	1.6	2267.1	.0	.0	.0	.0	.0	.0	.0
44	3.4	4198.1	.0	.0	.0	.0	.0	.0	.0

Unit Weight of Fill and Hide Residue = 115 pcf



EHP SECTION F-F LONG TERM G.W.T. (CIRCULAR SURFACE)
REMEDIATED CONDITION: F.S. = 2.3 (SECTF2.IN)
Y - AXIS (ft)
0
32.88
65.75
98.63
131.50
164.38
X - AXIS (ft)
0
32.88
65.75
98.63
131.50
164.38
197.25
230.13
263.00

2/5

** PCSTABL5M **

by
Purdue University

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

Run Date: 5/11/92
Time of Run:
Run By: DOKL
Input Data Filename: SECTF2.IN
Output Filename: SECTF2.OUT
Plotted Output Filename: SECTF2.PLT

PROBLEM DESCRIPTION ISRT: SECTION F-F, REMEDIATED SLOPE FILE SECTF2.IN

BOUNDARY COORDINATES

11 Top Boundaries
54 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	1.00	72.00	6.00	72.00	5
2	6.00	72.00	9.00	70.00	5
3	9.00	70.00	12.00	72.00	5
4	12.00	72.00	24.00	76.00	1
5	24.00	76.00	47.00	80.00	1
6	47.00	80.00	62.00	84.00	1
7	62.00	84.00	100.00	96.00	1
8	100.00	96.00	137.00	108.00	1
9	137.00	108.00	157.00	110.00	1
10	157.00	110.00	195.00	112.00	1
11	195.00	112.00	263.00	114.30	1
12	12.00	72.00	22.00	72.50	3
13	22.00	72.50	24.00	73.00	2
14	24.00	73.00	47.00	77.00	2
15	47.00	77.00	62.00	81.00	2
16	62.00	81.00	100.00	93.00	2
17	100.00	93.00	137.00	105.00	2
18	137.00	105.00	157.00	107.00	2
19	157.00	107.00	195.00	109.00	2
20	195.00	109.00	263.00	111.00	2
21	22.00	72.50	41.00	74.00	3
22	41.00	74.00	68.00	78.00	3
23	68.00	78.00	73.00	80.00	3
24	73.00	80.00	82.00	82.00	3
25	82.00	82.00	92.00	86.00	3
26	92.00	86.00	99.00	88.00	3
27	99.00	88.00	114.00	94.00	3
28	114.00	94.00	120.00	96.00	3
29	120.00	96.00	129.00	100.00	3
30	129.00	100.00	133.00	102.00	3

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31	133.00	102.00	138.00	104.00	3
32	138.00	104.00	147.00	105.90	3
33	147.00	105.90	206.00	108.00	3
34	206.00	108.00	263.00	107.50	3
35	12.00	72.00	48.00	69.00	5
36	48.00	69.00	56.00	72.00	4
37	56.00	72.00	62.00	73.60	4
38	62.00	73.60	68.00	74.50	4
39	68.00	74.50	73.00	76.50	4
40	73.00	76.50	82.00	78.50	4
41	82.00	78.50	92.00	83.00	4
42	92.00	83.00	99.00	85.00	4
43	99.00	85.00	114.00	91.00	4
44	114.00	91.00	120.00	93.00	4
45	120.00	93.00	125.00	95.00	4
46	125.00	95.00	138.00	101.00	4
47	138.00	101.00	147.00	103.00	4
48	147.00	103.00	206.00	105.00	4
49	206.00	105.00	263.00	104.50	4
50	48.00	69.00	167.00	68.50	5
51	167.00	68.50	183.00	68.50	6
52	183.00	68.50	263.00	71.50	6
53	.00	62.00	48.00	62.00	6
54	48.00	62.00	167.00	68.50	6

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ISOTROPIC SOIL PARAMETERS

6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	120.0	120.0	.0	.0	.00	.0	1
2	125.0	125.0	.0	33.0	.00	.0	1
3	90.0	100.0	.0	25.0	.00	.0	1
4	92.0	115.0	.0	34.0	.00	.0	1
5	120.0	120.0	.0	36.0	.00	.0	1
6	125.0	125.0	.0	37.0	.00	.0	1

1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 4 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	9.00	70.00
2	75.50	77.00
3	178.00	80.00
4	263.00	82.00

1

4/5

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

400 Trial Surfaces Have Been Generated.

20 Surfaces Initiate From Each Of 20 Points Equally Spaced Along The Ground Surface Between X = 10.00 ft.
and X = 70.00 ft.

Each Surface Terminates Between X = 130.00 ft.
and X = 160.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = .00 ft.

5.00 ft. Line Segments Define Each Trial Failure Surface.

Restrictions Have Been Imposed Upon The Angle Of Initiation. The Angle Has Been Restricted Between The Angles Of -45.0 And -20.0 deg.

1

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 27 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	22.63	75.54
2	27.32	73.81
3	32.10	72.32
4	36.94	71.08
5	41.84	70.08
6	46.78	69.32
7	51.75	68.82
8	56.75	68.57
9	61.75	68.57
10	66.74	68.83
11	71.72	69.33
12	76.66	70.09
13	81.56	71.09
14	86.40	72.34
15	91.17	73.84
16	95.86	75.57
17	100.46	77.54
18	104.95	79.73
19	109.32	82.15
20	113.57	84.79
21	117.68	87.64

5/5

22	121.64	90.69
23	125.44	93.94
24	129.07	97.38
25	132.52	100.99
26	135.79	104.78
27	138.41	108.14

Circle Center At X = 59.2 ; Y = 167.6 and Radius, 99.0

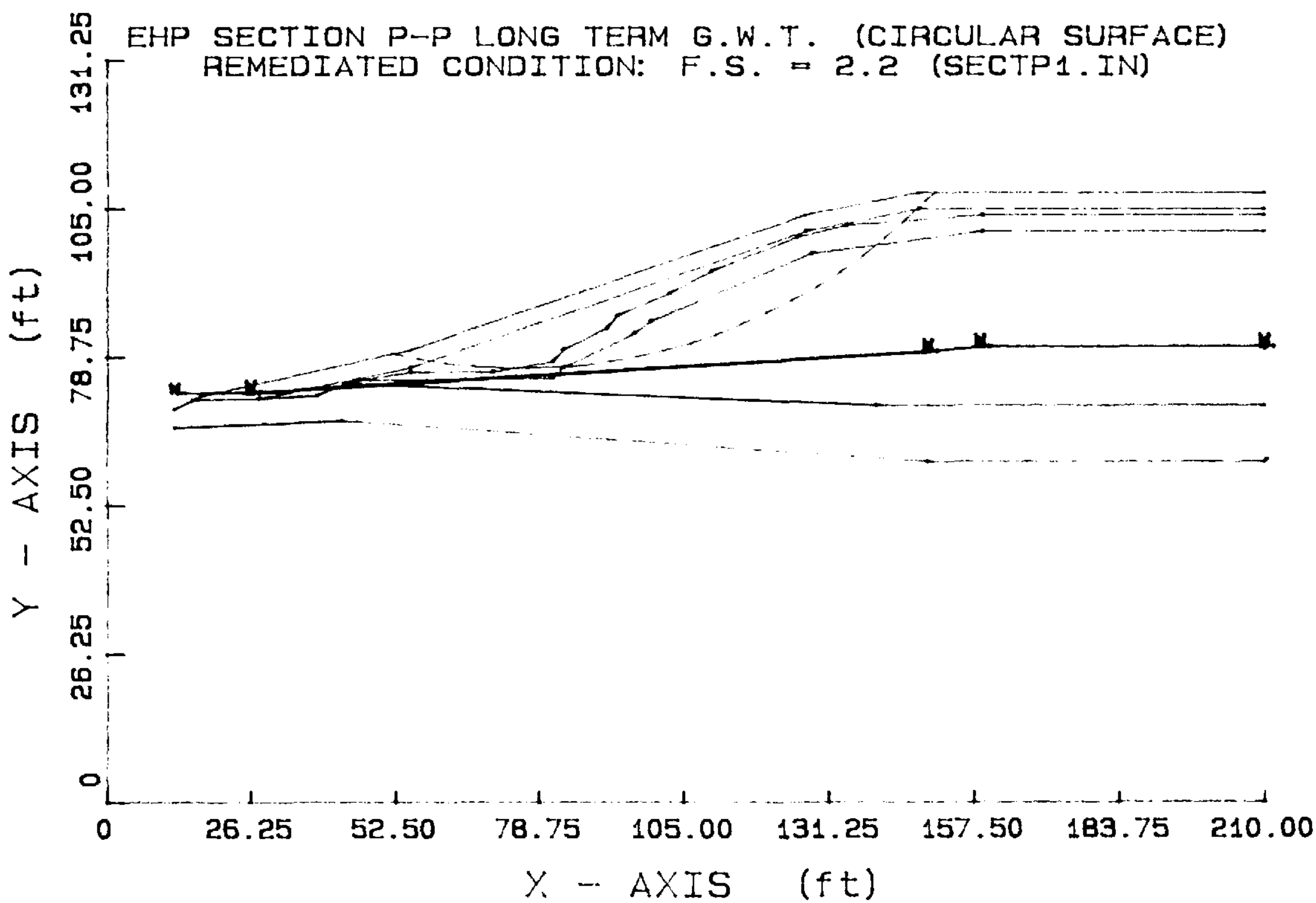
*** 2.316 ***

Individual data on the 55 slices

Slice No.	Width Ft(m)	Weight Lbs(kg)	Water Force Top Lbs(kg)	Water Force Bot Lbs(kg)	Tie Force Norm Lbs(kg)	Tie Force Tan Lbs(kg)	Earthquake Force Hor Lbs(kg)	Earthquake Force Ver Lbs(kg)	Surcharge Load Lbs(kg)
1	1.4	78.8	.0	.0	.0	.0	.0	.0	.0
2	3.3	742.5	.0	.0	.0	.0	.0	.0	.0
3	.5	168.4	.0	.0	.0	.0	.0	.0	.0
4	1.8	746.2	.0	.0	.0	.0	.0	.0	.0
5	2.2	1164.1	.0	.0	.0	.0	.0	.0	.0
6	.3	148.5	.0	.9	.0	.0	.0	.0	.0
7	4.8	3381.0	.0	305.7	.0	.0	.0	.0	.0
8	4.1	3620.2	.0	641.4	.0	.0	.0	.0	.0
9	.8	827.9	.0	172.3	.0	.0	.0	.0	.0
10	4.9	5369.9	.0	1246.6	.0	.0	.0	.0	.0
11	.2	257.8	.0	64.2	.0	.0	.0	.0	.0
	1.4	1704.5	.0	428.8	.0	.0	.0	.0	.0
[illegible]	1.6	2078.8	.0	528.0	.0	.0	.0	.0	.0
14	1.7	2281.0	.0	582.3	.0	.0	.0	.0	.0
15	4.2	6248.1	.0	1585.5	.0	.0	.0	.0	.0
16	.7	1176.9	.0	297.5	.0	.0	.0	.0	.0
17	5.0	8352.5	.0	2084.9	.0	.0	.0	.0	.0
18	.3	442.4	.0	109.3	.0	.0	.0	.0	.0
19	4.7	8699.9	.0	2099.0	.0	.0	.0	.0	.0
20	.9	1743.1	.0	410.7	.0	.0	.0	.0	.0
21	.4	679.4	.0	158.8	.0	.0	.0	.0	.0
22	3.7	7358.4	.0	1683.8	.0	.0	.0	.0	.0
23	1.3	2604.4	.0	583.6	.0	.0	.0	.0	.0
24	2.0	4165.0	.0	910.4	.0	.0	.0	.0	.0
25	.5	987.5	.0	211.8	.0	.0	.0	.0	.0
26	1.2	2424.5	.0	513.1	.0	.0	.0	.0	.0
27	4.9	10403.7	.0	2032.1	.0	.0	.0	.0	.0
28	.4	952.2	.0	172.4	.0	.0	.0	.0	.0
29	4.4	9420.4	.0	1552.5	.0	.0	.0	.0	.0
30	4.8	10092.1	.0	1340.8	.0	.0	.0	.0	.0
31	.8	1733.8	.0	192.3	.0	.0	.0	.0	.0
32	3.9	7943.5	.0	688.7	.0	.0	.0	.0	.0
33	3.1	6301.0	.0	298.5	.0	.0	.0	.0	.0
34	1.0	1966.3	.0	39.1	.0	.0	.0	.0	.0
35	.5	890.1	.0	8.8	.0	.0	.0	.0	.0
36	.4	820.9	.0	2.9	.0	.0	.0	.0	.0
37	4.1	7720.3	.0	.0	.0	.0	.0	.0	.0
38	4.4	7919.6	.0	.0	.0	.0	.0	.0	.0
39	4.2	7200.6	.0	.0	.0	.0	.0	.0	.0
	.4	697.7	.0	.0	.0	.0	.0	.0	.0
[illegible]	3.7	5715.1	.0	.0	.0	.0	.0	.0	.0
42	2.3	3347.3	.0	.0	.0	.0	.0	.0	.0
43	1.6	2224.3	.0	.0	.0	.0	.0	.0	.0
44	3.4	4139.0	.0	.0	.0	.0	.0	.0	.0

Section P-P' - Remediated Conditions
Circular - Long-Term Water Table
Unit Weights of Fill and Hide Residue = 115 and 125 pcf

Unit Weight of Fill and Hide Residue = 125 pcf



EHP SECTION P-P LONG TERM G.W.T. (CIRCULAR SURFACE)
REMEDIATED CONDITION: F.S. = 2.2 (SECTP1.IN)
Y - AXIS (ft)
0
26.25
52.50
78.75
105.00
131.25
X - AXIS (ft)
0
26.25
52.50
78.75
105.00
131.25
157.50
183.75
210.00

1

** PCSTABL5M **

by
Purdue University

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

Run Date:	5/7/92
Time of Run:	
Run By:	DOKL
Input Data Filename:	SECTP1.IN
Output Filename:	SECTP1.OUT
Plotted Output Filename:	SECTP1.PLT

PROBLEM DESCRIPTION   ISRT: SECTION P-P, REMEDIATED SLOPE FILE
SECTP1.IN

BOUNDARY COORDINATES

6 Top Boundaries
38 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	12.00	69.50	15.40	71.20	5
2	15.40	71.20	17.00	72.00	1
3	17.00	72.00	55.00	80.00	1
4	55.00	80.00	127.00	104.00	1
5	127.00	104.00	147.50	108.00	1
6	147.50	108.00	210.00	108.00	1
7	15.40	71.20	27.50	71.50	5
8	27.50	71.50	55.00	77.00	2
9	55.00	77.00	127.00	101.00	2
10	127.00	101.00	147.50	105.00	2
11	147.50	105.00	210.00	105.00	2
12	27.50	71.50	38.00	72.00	5
13	38.00	72.00	43.00	74.00	5
14	43.00	74.00	45.00	74.50	4
15	45.00	74.50	55.00	76.00	3
16	55.00	76.00	70.00	76.00	3
17	70.00	76.00	81.00	78.00	3
18	81.00	78.00	83.00	80.00	3
19	83.00	80.00	91.00	84.00	3
20	91.00	84.00	93.00	86.00	3
21	93.00	86.00	102.50	90.00	3
22	102.50	90.00	110.00	94.00	3
23	110.00	94.00	125.50	100.00	3
24	125.50	100.00	134.50	102.00	3
25	134.50	102.00	159.00	104.00	3
26	159.00	104.00	210.00	104.00	3
27	45.00	74.50	81.00	75.00	4
28	81.00	75.00	83.00	77.00	4
29	83.00	77.00	96.00	83.00	4
30	96.00	83.00	99.00	85.00	4

31	99.00	85.00	128.00	97.20	4
32	128.00	97.20	159.00	101.00	4
33	159.00	101.00	210.00	101.00	4
34	43.00	74.00	140.00	70.00	5
35	140.00	70.00	210.00	70.00	5
36	12.00	66.20	42.50	67.50	6
37	42.50	67.50	149.00	60.20	6
38	149.00	60.20	210.00	60.20	6

ISOTROPIC SOIL PARAMETERS

6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	120.0	120.0	.0	.0	.00	.0	1
2	125.0	125.0	.0	33.0	.00	.0	1
3	90.0	100.0	.0	25.0	.00	.0	1
4	100.0	125.0	.0	31.0	.00	.0	1
5	120.0	120.0	.0	36.0	.00	.0	1
6	125.0	125.0	.0	37.0	.00	.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 5 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	12.00	72.00
2	26.00	72.00
3	149.00	79.20
4	158.50	80.00
5	210.00	80.00

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

400 Trial Surfaces Have Been Generated.

20 Surfaces Initiate From Each Of 20 Points Equally Spaced Along The Ground Surface Between X = 50.00 ft. and X = 60.00 ft.

Each Surface Terminates Between X = 150.00 ft. and X = 170.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = .00 ft.

5.00 ft. Line Segments Define Each Trial Failure Surface.

Restrictions Have Been Imposed Upon The Angle Of Initiation. The Angle Has Been Restricted Between The Angles Of -45.0 And -10.0 deg.

1

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	51.58	79.28
2	56.48	78.29
3	61.42	77.53
4	66.39	77.00
5	71.39	76.71
6	76.39	76.65
7	81.38	76.83
8	86.36	77.24
9	91.32	77.89
10	96.25	78.77
11	101.12	79.88
12	105.94	81.22
13	110.69	82.78
14	115.36	84.56
15	119.94	86.57
16	124.42	88.78
17	128.79	91.21
18	133.05	93.84
19	137.17	96.66
20	141.16	99.68
21	145.00	102.88
22	148.69	106.25
23	150.43	108.00

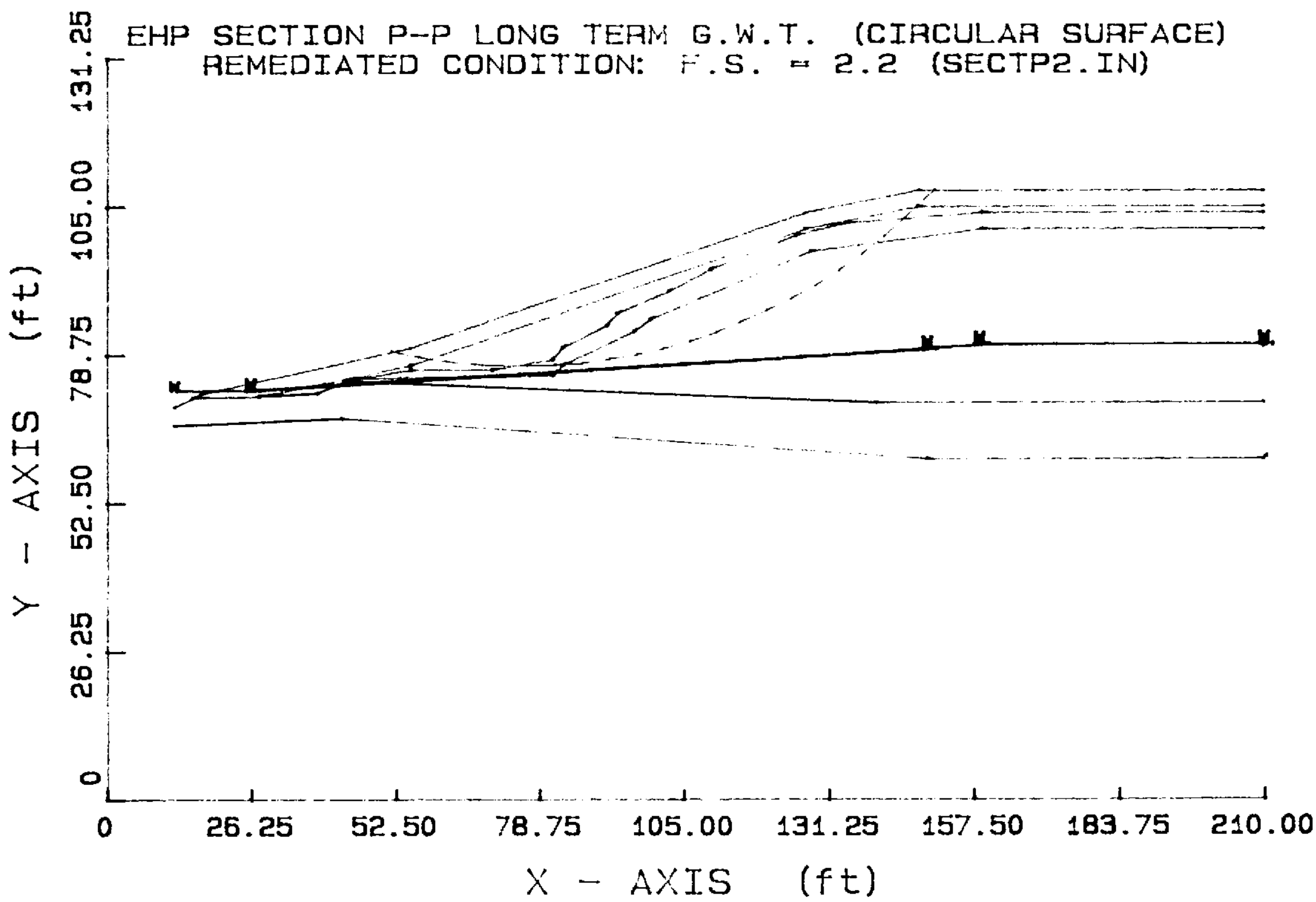
Circle Center At X = 75.1 ; Y = 182.9 and Radius, 106.3

*** 2.189 ***

Individual data on the 42 slices

Water Water Tie Tie Earthquake

Unit Weight of Fill and Hide Residue = 115 pcf



EHP SECTION P-P LONG TERM G.W.T. (CIRCULAR SURFACE)
REMEDIATED CONDITION: F.S. = 2.2 (SECTP2.IN)
Y - AXIS (ft)
131.25
105.00
78.75
52.50
26.25
0
26.25
52.50
78.75
105.00
131.25
157.50
183.75
210.00
X - AXIS (ft)

** PCSTABL5M **

by
Purdue University

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

Run Date: 5/7/92
Time of Run:
Run By: DOKL
Input Data Filename: SECTP2.IN
Output Filename: SECTP2.OUT
Plotted Output Filename: SECTP2.PLT

PROBLEM DESCRIPTION ISRT: SECTION P-P, REMEDIATED SLOPE FILE SECTP2.IN

BOUNDARY COORDINATES

6 Top Boundaries
38 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	12.00	69.50	15.40	71.20	5
2	15.40	71.20	17.00	72.00	1
3	17.00	72.00	55.00	80.00	1
4	55.00	80.00	127.00	104.00	1
5	127.00	104.00	147.50	108.00	1
6	147.50	108.00	210.00	108.00	1
7	15.40	71.20	27.50	71.50	5
8	27.50	71.50	55.00	77.00	2
9	55.00	77.00	127.00	101.00	2
10	127.00	101.00	147.50	105.00	2
11	147.50	105.00	210.00	105.00	2
12	27.50	71.50	38.00	72.00	5
13	38.00	72.00	43.00	74.00	5
14	43.00	74.00	45.00	74.50	4
15	45.00	74.50	55.00	76.00	3
16	55.00	76.00	70.00	76.00	3
17	70.00	76.00	81.00	78.00	3
18	81.00	78.00	83.00	80.00	3
19	83.00	80.00	91.00	84.00	3
20	91.00	84.00	93.00	86.00	3
21	93.00	86.00	102.50	90.00	3
22	102.50	90.00	110.00	94.00	3
23	110.00	94.00	125.50	100.00	3
24	125.50	100.00	134.50	102.00	3
25	134.50	102.00	159.00	104.00	3
26	159.00	104.00	210.00	104.00	3
27	45.00	74.50	81.00	75.00	4
28	81.00	75.00	83.00	77.00	4
29	83.00	77.00	96.00	83.00	4
30	96.00	83.00	99.00	85.00	4

31	99.00	85.00	128.00	97.20	4
32	128.00	97.20	159.00	101.00	4
33	159.00	101.00	210.00	101.00	4
34	43.00	74.00	140.00	70.00	5
35	140.00	70.00	210.00	70.00	5
36	12.00	66.20	42.50	67.50	6
37	42.50	67.50	149.00	60.20	6
38	149.00	60.20	210.00	60.20	6

ISOTROPIC SOIL PARAMETERS

6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	120.0	120.0	.0	.0	.00	.0	1
2	125.0	125.0	.0	33.0	.00	.0	1
3	90.0	100.0	.0	25.0	.00	.0	1
4	92.0	115.0	.0	31.0	.00	.0	1
5	120.0	120.0	.0	36.0	.00	.0	1
6	125.0	125.0	.0	37.0	.00	.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 5 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	12.00	72.00
2	26.00	72.00
3	149.00	79.20
4	158.50	80.00
5	210.00	80.00

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

400 Trial Surfaces Have Been Generated.

20 Surfaces Initiate From Each Of 20 Points Equally Spaced Along The Ground Surface Between X = 50.00 ft. and X = 60.00 ft.

Each Surface Terminates Between X = 150.00 ft. and X = 170.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = .00 ft.

5.00 ft. Line Segments Define Each Trial Failure Surface.

Restrictions Have Been Imposed Upon The Angle Of Initiation. The Angle Has Been Restricted Between The Angles Of -45.0 And -10.0 deg.

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	51.58	79.28
2	56.48	78.29
3	61.42	77.53
4	66.39	77.00
5	71.39	76.71
6	76.39	76.65
7	81.38	76.83
8	86.36	77.24
9	91.32	77.89
10	96.25	78.77
11	101.12	79.88
12	105.94	81.22
13	110.69	82.78
14	115.36	84.56
15	119.94	86.57
16	124.42	88.78
17	128.79	91.21
18	133.05	93.84
19	137.17	96.66
20	141.16	99.68
21	145.00	102.88
22	148.69	106.25
23	150.43	108.00

Circle Center At X = 75.1 ; Y = 182.9 and Radius, 106.3

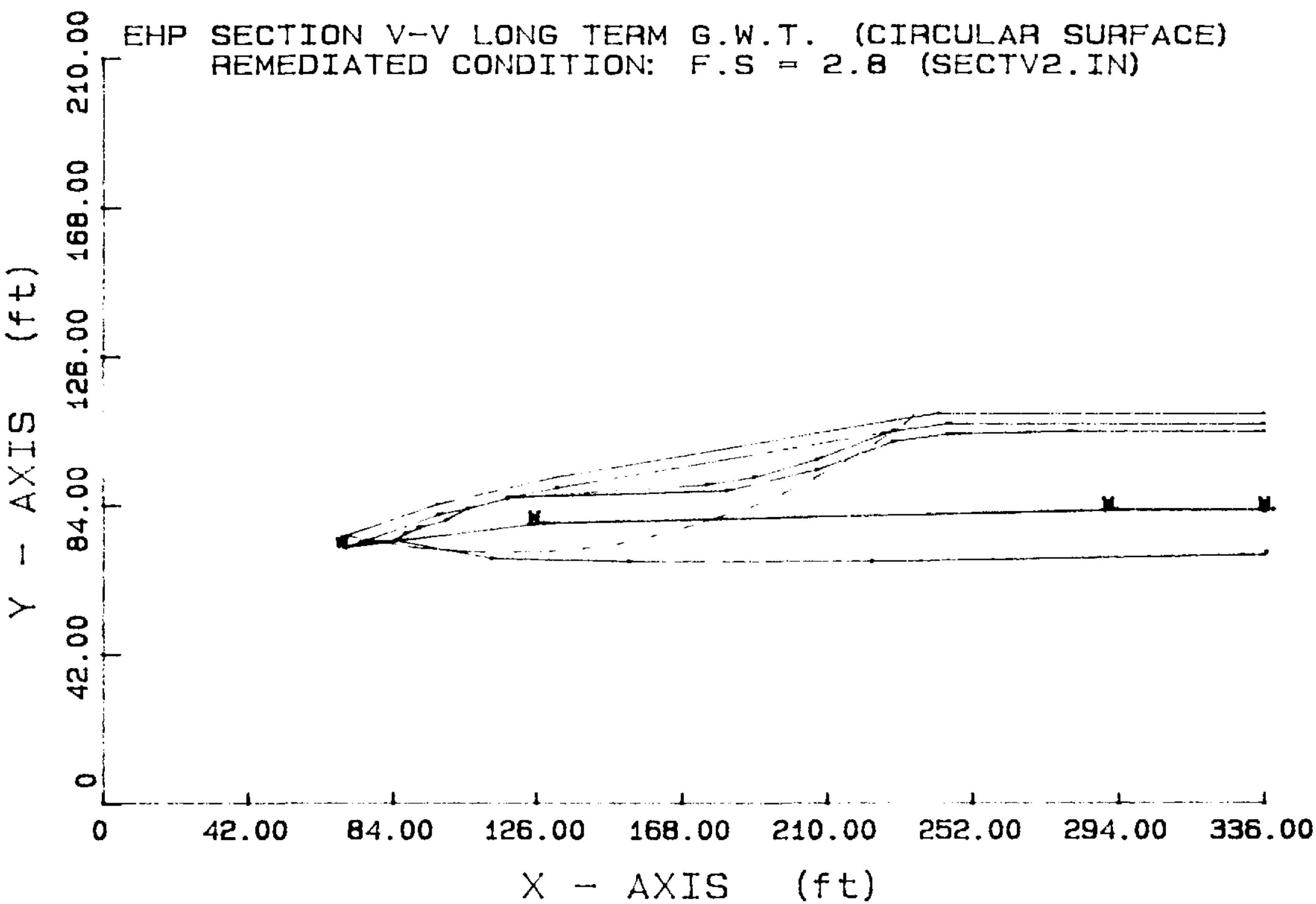
*** 2.206 ***

Individual data on the 42 slices

Water Water Tie Tie Earthquake

Section V-V' - Remediated Conditions
Circular - Long-Term Water Table
Unit Weights of Fill and Hide Residue = 115 and 125 pcf

Unit Weight of Fill and Hide Residue = 125 pcf


EHP SECTION V-V LONG TERM G.W.T. (CIRCULAR SURFACE)
REMEDIATED CONDITION: F.S = 2.8 (SECTV2.IN)
Y - AXIS (ft)
X - AXIS (ft)
0
42.00
84.00
126.00
168.00
210.00
252.00
294.00
336.00

** PCSTABL5M **

by
Purdue University

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

Run Date: 5/8/92
Time of Run:
Run By: DOKL
Input Data Filename: SECTV2.IN
Output Filename: SECTV2.OUT
Plotted Output Filename: SECTV2.PLT

PROBLEM DESCRIPTION ISRT: SECTION V-V, REMEDIATED SLOPE FILE SECTV2.IN

BOUNDARY COORDINATES

5 Top Boundaries
33 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	69.00	75.00	96.50	84.30	1
2	96.50	84.30	131.00	92.00	1
3	131.00	92.00	228.00	108.00	1
4	228.00	108.00	242.00	110.00	1
5	242.00	110.00	336.00	110.00	1
6	70.00	72.00	74.50	73.50	5
7	74.50	73.50	97.00	81.30	2
8	97.00	81.30	105.50	83.00	2
9	105.50	83.00	117.50	86.00	4
10	117.50	86.00	132.00	89.00	2
11	132.00	89.00	229.00	105.00	2
12	229.00	105.00	245.00	107.00	3
13	245.00	107.00	336.00	107.00	3
14	117.50	86.00	175.00	90.00	3
15	175.00	90.00	189.00	92.00	3
16	189.00	92.00	207.00	97.00	3
17	207.00	97.00	226.00	104.00	3
18	226.00	104.00	229.00	105.00	3
19	117.50	86.00	181.00	88.00	4
20	181.00	88.00	207.00	94.00	4
21	207.00	94.00	229.00	102.00	4
22	229.00	102.00	245.00	104.00	4
23	245.00	104.00	280.00	105.00	4
24	280.00	105.00	336.00	105.00	4
25	74.50	73.50	84.50	74.00	5
26	84.50	74.00	87.50	76.00	4
27	87.50	76.00	91.00	77.50	4
28	91.00	77.50	99.00	80.00	4
29	99.00	80.00	105.50	83.00	4
30	84.50	74.00	112.50	69.00	5

31	112.50	69.00	152.50	68.00	5
32	152.50	68.00	222.50	68.00	5
33	222.50	68.00	336.00	70.00	5

1

ISOTROPIC SOIL PARAMETERS

5 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	120.0	120.0	.0	.0	.00	.0	1
2	125.0	125.0	.0	33.0	.00	.0	1
3	90.0	100.0	.0	25.0	.00	.0	1
4	100.0	125.0	.0	28.0	.00	.0	1
5	120.0	120.0	.0	36.0	.00	.0	1

1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 4 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	69.00	71.50
2	125.00	78.00
3	291.00	82.00
4	336.00	82.00

1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

400 Trial Surfaces Have Been Generated.

20 Surfaces Initiate From Each Of 20 Points Equally Spaced
Along The Ground Surface Between X = 70.00 ft.
and X = 180.00 ft.

Each Surface Terminates Between X = 230.00 ft.
and X = 260.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = .00 ft.

10.00 ft. Line Segments Define Each Trial Failure Surface.

Restrictions Have Been Imposed Upon The Angle Of Initiation.
The Angle Has Been Restricted Between The Angles Of -45.0
And -5.0 deg.

Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 19 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	70.00	75.34
2	79.81	73.39
3	89.70	71.93
4	99.65	70.94
5	109.64	70.44
6	119.64	70.43
7	129.63	70.90
8	139.58	71.85
9	149.48	73.29
10	159.30	75.20
11	169.01	77.59
12	178.59	80.45
13	188.02	83.77
14	197.28	87.54
15	206.35	91.75
16	215.20	96.40
17	223.82	101.48
18	232.18	106.97
19	234.97	109.00

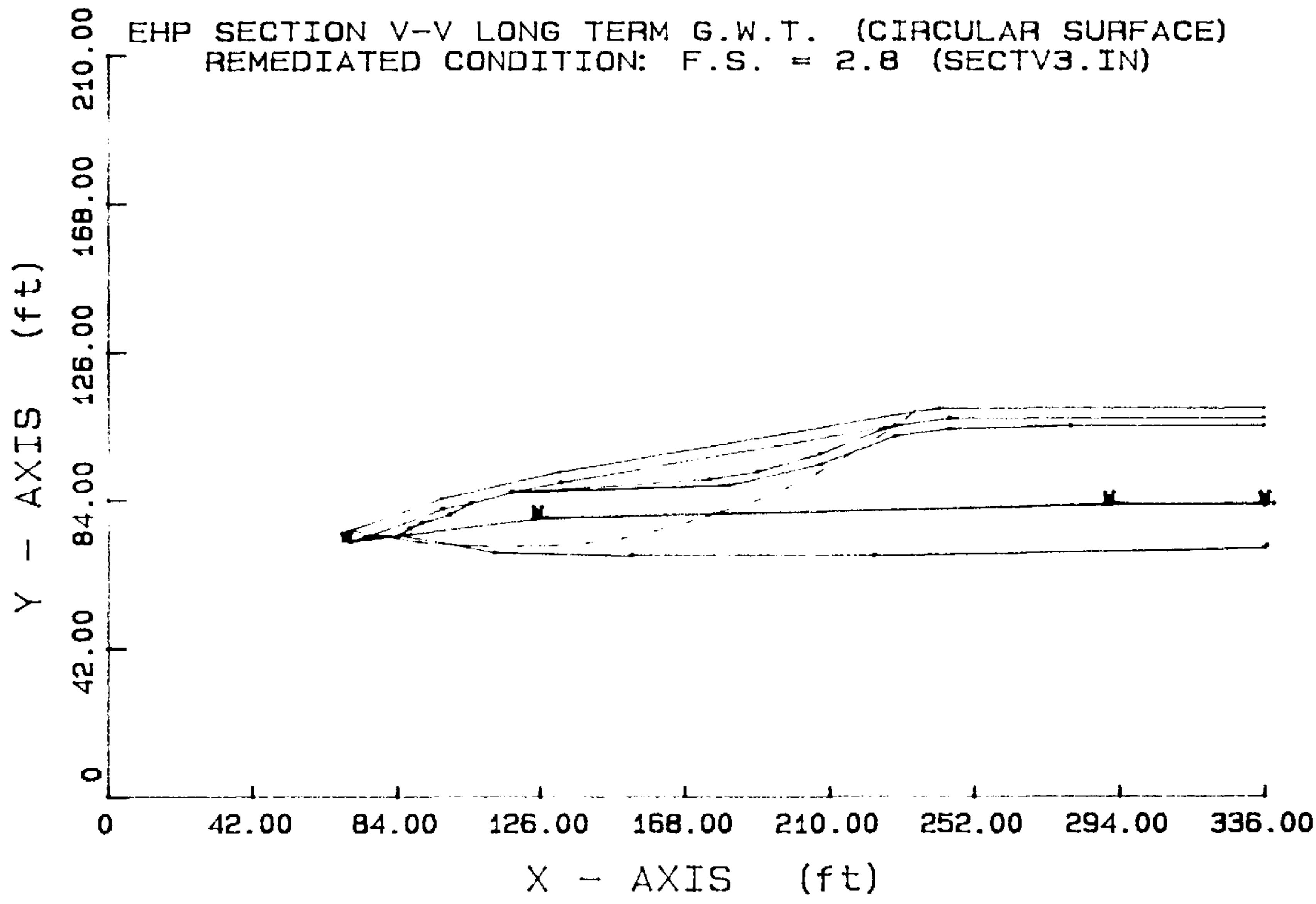
Circle Center At X = 115.0 ; Y = 276.5 and Radius, 206.1

*** 2.804 ***

Individual data on the 44 slices

Slice No.	Width Ft(m)	Weight Lbs(kg)	Water Force Top Lbs(kg)	Water Force Bot Lbs(kg)	Tie Force Norm Lbs(kg)	Tie Force Tan Lbs(kg)	Earthquake Force Hor Lbs(kg)	Earthquake Force Ver Lbs(kg)	Surcharge Load Lbs(kg)
1	6.2	1251.9	.0	.0	.0	.0	.0	.0	.0
2	2.1	978.7	.0	.0	.0	.0	.0	.0	.0
3	1.5	881.8	.0	.0	.0	.0	.0	.0	.0
4	2.4	1723.5	.0	.0	.0	.0	.0	.0	.0
5	2.3	1932.7	.0	42.6	.0	.0	.0	.0	.0
6	2.4	2301.0	.0	136.2	.0	.0	.0	.0	.0
7	.6	639.3	.0	51.0	.0	.0	.0	.0	.0
8	2.2	2427.0	.0	232.2	.0	.0	.0	.0	.0

Unit Weight of Fill and Hide Residue = 115 pcf


EHP SECTION V-V LONG TERM G.W.T. (CIRCULAR SURFACE)
REMEDIATED CONDITION: F.S. = 2.8 (SECTV3.IN)
Y - AXIS (ft)
0
42.00
84.00
126.00
168.00
210.00
X - AXIS (ft)
0
42.00
84.00
126.00
168.00
210.00
252.00
294.00
336.00

2/4

** PCSTABL5M **

by
Purdue University

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

Run Date: 5/8/92
Time of Run:
Run By: DOKL
Input Data Filename: SECTV3.IN
Output Filename: SECTV3.OUT
Plotted Output Filename: SECTV3.PLT

PROBLEM DESCRIPTION ISRT: SECTION V-V, REMEDIATED SLOPE FILE
SECTV3.IN

BOUNDARY COORDINATES

5 Top Boundaries
33 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	69.00	75.00	96.50	84.30	1
2	96.50	84.30	131.00	92.00	1
3	131.00	92.00	228.00	108.00	1
4	228.00	108.00	242.00	110.00	1
5	242.00	110.00	336.00	110.00	1
6	70.00	72.00	74.50	73.50	5
7	74.50	73.50	97.00	81.30	2
8	97.00	81.30	105.50	83.00	2
9	105.50	83.00	117.50	86.00	4
10	117.50	86.00	132.00	89.00	2
11	132.00	89.00	229.00	105.00	2
12	229.00	105.00	245.00	107.00	3
13	245.00	107.00	336.00	107.00	3
14	117.50	86.00	175.00	90.00	3
15	175.00	90.00	189.00	92.00	3
16	189.00	92.00	207.00	97.00	3
17	207.00	97.00	226.00	104.00	3
18	226.00	104.00	229.00	105.00	3
19	117.50	86.00	181.00	88.00	4
20	181.00	88.00	207.00	94.00	4
21	207.00	94.00	229.00	102.00	4
22	229.00	102.00	245.00	104.00	4
23	245.00	104.00	280.00	105.00	4
24	280.00	105.00	336.00	105.00	4
25	74.50	73.50	84.50	74.00	5
26	84.50	74.00	87.50	76.00	4
27	87.50	76.00	91.00	77.50	4
28	91.00	77.50	99.00	80.00	4
29	99.00	80.00	105.50	83.00	4
30	84.50	74.00	112.50	69.00	5

31	112.50	69.00	152.50	68.00	5
32	152.50	68.00	222.50	68.00	5
33	222.50	68.00	336.00	70.00	5

ISOTROPIC SOIL PARAMETERS

5 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	120.0	120.0	.0	.0	.00	.0	1
2	125.0	125.0	.0	33.0	.00	.0	1
3	90.0	100.0	.0	25.0	.00	.0	1
4	92.0	115.0	.0	28.0	.00	.0	1
5	120.0	120.0	.0	36.0	.00	.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 4 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	69.00	71.50
2	125.00	78.00
3	291.00	82.00
4	336.00	82.00

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

400 Trial Surfaces Have Been Generated.

20 Surfaces Initiate From Each Of 20 Points Equally Spaced Along The Ground Surface Between X = 70.00 ft. and X = 180.00 ft.

Each Surface Terminates Between X = 230.00 ft. and X = 260.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = .00 ft.

10.00 ft. Line Segments Define Each Trial Failure Surface.

4/4

Restrictions Have Been Imposed Upon The Angle Of Initiation.
The Angle Has Been Restricted Between The Angles Of -45.0
And -5.0 deg.

Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 19 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	70.00	75.34
2	79.81	73.39
3	89.70	71.93
4	99.65	70.94
5	109.64	70.44
6	119.64	70.43
7	129.63	70.90
8	139.58	71.85
9	149.48	73.29
10	159.30	75.20
11	169.01	77.59
12	178.59	80.45
13	188.02	83.77
14	197.28	87.54
15	206.35	91.75
16	215.20	96.40
17	223.82	101.48
18	232.18	106.97
19	234.97	109.00

Circle Center At X = 115.0 ; Y = 276.5 and Radius, 206.1

*** 2.756 ***

Individual data on the 44 slices

Slice No.	Width Ft(m)	Weight Lbs(kg)	Water Force Top Lbs(kg)	Water Force Bot Lbs(kg)	Tie Force Norm Lbs(kg)	Tie Force Tan Lbs(kg)	Earthquake Force Hor Lbs(kg)	Earthquake Force Ver Lbs(kg)	Surcharge Load Lbs(kg)
1	6.2	1251.9	.0	.0	.0	.0	.0	.0	.0
2	2.1	978.7	.0	.0	.0	.0	.0	.0	.0
3	1.5	881.8	.0	.0	.0	.0	.0	.0	.[illegible]
4	2.4	1723.5	.0	.0	.0	.0	.0	.0	.[illegible]
5	2.3	1932.7	.0	42.6	.0	.0	.0	.0	.0
6	2.4	2281.9	.0	136.2	.0	.0	.0	.0	.0
7	.6	627.9	.0	51.0	.0	.0	.0	.0	.0
8	2.2	2368.4	.0	232.2	.0	.0	.0	.0	.0

APPENDIX 12-D

Soil Erosion Calculations

Golder Associates	SUBJECT Soil Erosion		
	Job No. 903-6410.210 Ref. ISRT/Woburn/Mass	Made by NLC Checked UEE7 Reviewed M.R.	Date 12/12/91 Sheet 1 of 8

Objective; estimate the amount of soil loss on the steepest slope section of the cover on the East Hide Pile

Method: calculate the average annual erosion using the Universal Soil Loss Equation (USDA):

$$A = R \times K \times LS \times C \times P$$

where A = avg. annual soil loss, tons/acre

R = rainfall and runoff erosivity index

K = soil erodibility factor, tons/acre

LS = slope length - steepness factor

C = cover management factor

P = erosion control practice factor

References: 1. "Evaluating Cover Systems for Solid and Hazardous Waste", (EPA-530-SW-867), R.J. Lutton

2. Standards for Soil Erosion and Sediment Control in New Jersey, 1987

3. Sheet 12-1 of this report

Assumptions: R = 125 (from fig. 20 of ref1)

K = 0.24 (from Table 5 of ref1 for a sandy loam with 2% organic content)

C = 0.004 (from Table 7 of ref1 for grass and legume meadow, high productivity)

P = 1.0 (from Table 8 of ref1 - conservative value)

steepest slope section (see sheet 12-1 at section W-W' - down to 72' contour): total length = 140'

Golder Associates	SUBJECT Soil Erosion		
	Job No. 903-0490	Made by FLK	Date 12/12/91
	Ref. ISRT/Wabaren/Mns	Checked VSE7	Sheet 2 of 8
		Reviewed	

Calculations:

slope segments:

1	10% slope	20 ft. long
2	33% slope	100 ft. long
3	20% slope	20 ft. long - assume also to have

33% slope to simplify calcs and to be conservative

therefore model as 2 equal segments each of 20 feet length and add soil loss from remaining 100 foot segment at 33% slope

from Table A1-3 of ref 2 (which is used because it contains a greater # of values)

$LS_{10\%} = 0.87$ for length = 40 ft

$LS_{33\%} = 6.0$ for length = 40 ft ; $LS_{33\%} = 9.67$ for length = 100 ft

multiply these values by factors from p. 39 of ref 1 for 2 segments to determine an effective LS value

$LS_{eff} = (0.87 \times 0.71 + 6.0 \times 1.29)/2 = 4.18$

for the two equal segments $A = R \times K \times LS \times C \times P$

$= 125 \times 0.24 \times 4.18 \times 0.004 \times 1.0$ (tons/acre/yr)

$= 0.50$ (tons/acre/yr)

for remaining 100 feet $A = R \times K \times LS \times C \times P$

$= 125 \times 0.24 \times 9.67 \times 0.004 \times 1.0$ (tons/acre/yr)

$= 1.16$ (tons/acre/yr)

total $A = (0.50 + 1.16)$ (tons/acre/yr) $= 1.66$ (tons/acre/yr) < 2 (tons/acre/yr)

∴ calculated soil loss is less than permitted value stated in RDAP

3/8

Not only is erosion objectionable in itself but erosion can degrade the cover and seriously reduce its effectiveness.

<u>Evaluate Erosion Potential</u> <u>Step 19</u>

The USDA universal soil loss equation (USLE) is a convenient tool for use in evaluating erosion potential. The USLE predicts average annual soil loss as the product of six quantifiable factors. The equation is:

$$A = R\,K\,L\,S\,C\,P$$

where A = average annual soil loss, in tons/acre
R = rainfall and runoff erosivity index
K = soil erodibility factor, tons/acre
L = slope-length factor
S = slope-steepness factor
C = cover-management factor
P = practice factor

The data necessary as input to this equation are available to the evaluator in a figure and tables included below. Note that the evaluations in Step 8 on soil composition and Steps 25-32 on vegetation all impact on the evaluation of erosion also.

Factor R in the USLE can be calculated empirically from climatological data. For average annual soil loss determinations, however, R can be obtained directly from Figure 20. Factor K, the average soil loss for a given

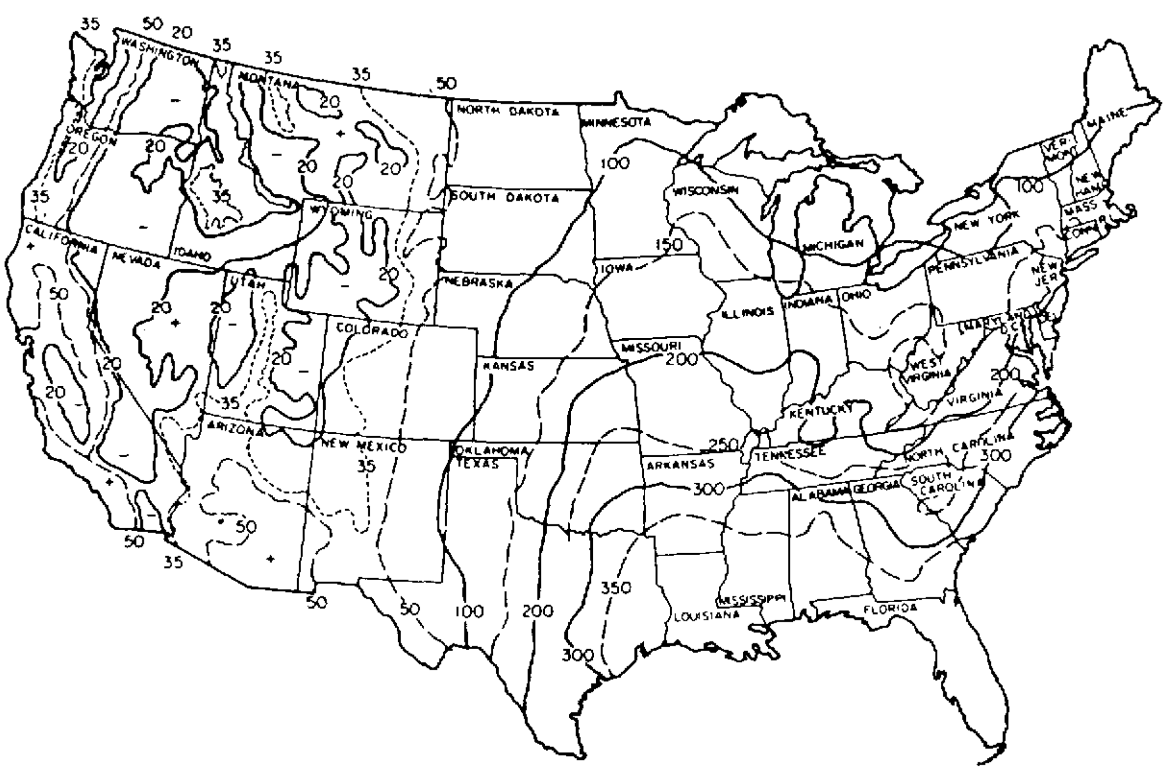


Figure 20. Average annual values of rainfall-erosivity factor R.[11]

from reference 1

4/8

soil in a unit plot, pinpoints differences in erosion according to differences in soil type. Long-term plot studies under natural rainfall have produced K values generalized in Table 5 for the USDA soil types.

TABLE 5. APPROXIMATE VALUES OF FACTOR K FOR USDA TEXTURAL CLASSES[11]

Texture class	Organic matter content		
	<0.5%	2%	4%
	K	K	K
Sand	0.05	0.03	0.02
Fine sand	.16	.14	.10
Very fine sand	.42	.36	.28
Loamy sand	.12	.10	.08
Loamy fine sand	.24	.20	.16
Loamy very fine sand	.44	.38	.30
Sandy loam	.27	.24	.19
Fine sandy loam	.35	.30	.24
Very fine sandy loam	.47	.41	.33
Loam	.38	.34	.29
Silt loam	.48	.42	.33
Silt	.60	.52	.42
Sandy clay loam	.27	.25	.21
Clay loam	.28	.25	.21
Silty clay loam	.37	.32	.26
Sandy clay	.14	.13	.12
Silty clay	.25	.23	.19
Clay		0.13-0.29	

The values shown are estimated averages of broad ranges of specific-soil values. When a texture is near the borderline of two texture classes, use the average of the two K values.

The evaluator must next consider the shape of the slope in terms of length and inclination. The appropriate LS factor is obtained from Table 6. A nonlinear slope may have to be evaluated as a series of segments, each with uniform gradient. Two or three segments should be sufficient for most engineered landfills, provided the segments are selected so that they are also of equal length (Table 6 can be used, with certain adjustments). Enter Table 6 with the total slope length and read LS values corresponding to the percent slope of each segment. For three segments, multiply the chart LS values for the upper, middle, and lower segments by 0.58, 1.06, and 1.37, respectively. The average of the three products is a good estimate of the

from reference 1

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TABLE 6. VALUES OF THE FACTOR LS FOR SPECIFIC COMBINATIONS OF SLOPE LENGTH AND STEEPNESS[11]

% Slope	Slope length (feet)											
	25	50	75	100	150	200	300	400	500	600	800	1000
0.5	0.07	0.08	0.09	0.10	0.11	0.12	0.14	0.15	0.16	0.17	0.19	0.20
1	0.09	0.10	0.12	0.13	0.15	0.16	0.18	0.20	0.21	0.22	0.24	0.26
2	0.13	0.16	0.19	0.20	0.23	0.25	0.28	0.31	0.33	0.34	0.38	0.40
3	0.19	0.23	0.26	0.29	0.33	0.35	0.40	0.44	0.47	0.49	0.54	0.57
4	0.23	0.30	0.36	0.40	0.47	0.53	0.62	0.70	0.76	0.82	0.92	1.0
5	0.27	0.38	0.46	0.54	0.66	0.76	0.93	1.1	1.2	1.3	1.5	1.7
6	0.34	0.48	0.58	0.67	0.82	0.95	1.2	1.4	1.5	1.7	1.9	2.1
8	0.50	0.70	0.86	0.99	1.2	1.4	1.7	2.0	2.2	2.4	2.8	3.1
10	0.69	0.97	1.2	1.4	1.7	1.9	2.4	2.7	3.1	3.4	3.9	4.3
12	0.90	1.3	1.6	1.8	2.2	2.6	3.1	3.6	4.0	4.4	5.1	5.7
14	1.2	1.6	2.0	2.3	2.8	3.3	4.0	4.6	5.1	5.6	6.5	7.3
16	1.4	2.0	2.5	2.8	3.5	4.0	4.9	5.7	6.4	7.0	8.0	9.0
18	1.7	2.4	3.0	3.4	4.2	4.9	6.0	6.9	7.7	8.4	9.7	11.0
20	2.0	2.9	3.5	4.1	5.0	5.8	7.1	8.2	9.1	10.0	12.0	13.0
25	3.0	4.2	5.1	5.9	7.2	8.3	10.0	12.0	13.0	14.0	17.0	19.0
30	4.0	5.6	6.9	8.0	9.7	11.0	14.0	16.0	18.0	20.0	23.0	25.0
40	6.3	9.0	11.0	13.0	16.0	18.0	22.0	25.0	28.0	31.0	--	--
50	8.9	13.0	15.0	18.0	22.0	25.0	31.0	--	--	--	--	--
60	12.0	16.0	20.0	23.0	28.0	--	--	--	--	--	--	--

Values given for slopes longer than 300 feet or steeper than 18% are extrapolations beyond the range of the research data and, therefore, less certain than the others.

overall effective LS value. If two segments are sufficient, multiply by 0.71 and 1.29.

Factor C in the USLE is the ratio of soil loss from land cropped under specified conditions to that from clean-tilled, continuous fallow. Therefore, C combines effects of vegetation, crop sequence, management, and agricultural (as opposed to engineering) erosion-control practices. On landfills, freshly covered and without vegetation or special erosion-reducing procedures of cover placement, C will usually be about unity. Where there is vegetative cover or significant amounts of gravel, roots, or plant residues or where cultural practices increase infiltration and reduce runoff velocity, C is much less than unity. Estimate C by reference to Table 7 for anticipated cover management, but also consider changes that may take place in time. Meadow values are usually most appropriate. See Reference 1 for additional guidance.

Factor P in the USLE is similar to C except that it accounts for additional erosion-reducing effects of land management practices that are superimposed on the cultural practices, e.g., contouring, terracing, and contour strip-cropping. Approximate values of P, related only to slope steepness,

from reference 1

from reference 2

TABLE A1-3

VALUES OF THE TOPOGRAPHIC FACTOR "LS"

Length of Slope (L) Ft.	Percent Slope (S) 0.2	0.3	0.4	0.5	1.0	2.0	3.0	4.0	5.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	25.0	30.0	40.0	50.0	60.0
20	.05	.05	.06	.06	.08	.12	.18	.21	.24	.30	.44	.61	.81	1.0	1.3	1.6	1.8	2.6	4	6	8	10
40	.06	.07	.07	.08	.10	.15	.22	.28	.34	.43	.63	.87	1.2	1.4	1.8	2.2	2.6	3.5	5	8	11	15
60	.07	.08	.08	.08	.11	.17	.25	.33	.41	.52	.77	1.0	1.4	1.8	2.2	2.6	3.0	4.5	6	10	14	18
80	.08	.08	.09	.09	.12	.19	.27	.37	.48	.60	.89	1.2	1.6	2.1	2.6	3.0	3.6	5.5	7	11	16	21
100	.08	.09	.09	.10	.13	.20	.29	.40	.54	.67	.99	1.4	1.8	2.4	2.9	3.5	4.2	6.0	8	13	18	23
110	.08	.09	.10	.10	.13	.21	.30	.42	.56	.71	1.0	1.5	2.0	2.5	3.0	3.7	4.5	6	9	14	19	25
120	.09	.09	.10	.10	.14	.21	.30	.43	.59	.74	1.0	1.6	2.1	2.6	3.3	4.0	4.6	7	9	14	20	26
130	.09	.09	.10	.11	.14	.22	.31	.44	.61	.77	1.2	1.6	2.2	2.8	3.4	4.1	4.9	7	9	15	20	27
140	.09	.10	.10	.11	.14	.22	.32	.46	.63	.80	1.2	1.7	2.3	2.9	3.6	4.3	5.1	7	10	15	21	29
150	.09	.10	.11	.11	.15	.23	.32	.47	.66	.82	1.2	1.8	2.4	3.0	3.7	4.5	5.3	8	10	16	23	30
160	.09	.10	.11	.11	.15	.23	.33	.48	.68	.85	1.2	1.9	2.5	3.1	3.9	4.7	5.5	8	10	17	24	31
180	.10	.10	.11	.12	.15	.24	.34	.51	.72	.90	1.4	1.9	2.6	3.3	4.1	5.0	6.0	9	12	18	26	33
200	.10	.11	.11	.12	.16	.25	.35	.53	.76	.95	1.4	2.1	2.8	3.6	4.4	5.3	6.3	9	12	18	27	35
300	.11	.12	.13	.14	.18	.28	.40	.62	.93	1.2	1.8	2.7	3.6	4.5	5.6	6.8	8	12	16	25	35	45
400	.12	.13	.14	.15	.20	.31	.44	.70	1.0	1.4	2.0	3.2	4.2	5.4	6.7	8.0	10	14	19	30	42	54
500	.13	.14	.15	.16	.21	.33	.47	.76	1.2	1.6	2.2	3.7	4.9	6.2	7.6	9.2	11	16	21	34	47	61
600	.14	.15	.16	.17	.22	.34	.49	.82	1.4	1.6	2.4	4.1	5.4	6.9	8.5	10.3	12	16	24	38	53	68
700	.15	.16	.17	.18	.23	.36	.52	.87	1.4	1.8	2.6	4.5	6.0	7.5	9.3	11.3	13	18	26	41	58	75
800	.15	.16	.17	.18	.24	.38	.54	.92	1.6	2.0	2.8	4.9	6.4	8.2	10.1	12.2	14	20	28	45	58	81
900	.16	.17	.18	.19	.25	.39	.56	.96	1.6	2.0	3.0	5.2	6.9	8.8	10.8	13.1	16	22	30	48	67	87
1000	.16	.18	.19	.20	.26	.40	.57	1.0	1.6	2.2	3.0	5.6	7.4	9.3	11.6	14.0	17	24	32	51	72	93

When the length of slope exceeds 400 feet and (or) percent of slope exceeds 24 percent, soil loss estimates are speculative as these values are beyond the range of research data.

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TABLE 7. GENERALIZED VALUES OF FACTOR C FOR STATES EAST OF THE ROCKY MOUNTAINS[11]

Crop, rotation, and management	Productivity level	
	High	Mod.
	C value	
Base value: continuous fallow, tilled up and down slope	1.00	1.00
CORN		
C, RdR, fall TP, conv	0.54	0.62
C, RdR, spring TP, conv	.50	.59
C, RdL, fall TP, conv	.42	.52
C, RdR, wc seeding, spring TP, conv	.40	.49
C, RdL, standing, spring TP, conv	.38	.48
C-W-M-M, RdL, TP for C, disk for W	.039	.074
C-W-M-M-M, RdL, TP for C, disk for W	.032	.061
C, no-till pl in c-k sod, 95-80% rc	.017	.053
COTTON		
Cot, conv (Western Plains)	0.42	0.49
Cot, conv (South)	.34	.40
MEADOW		
Grass & Legume mix	0.004	0.01
Alfalfa, lespodeza or Sericia	.020	
Sweet clover	.025	
SORGHUM, GRAIN (Western Plains)		
RdL, spring TP, conv	0.43	0.53
No-till pl in shredded 70-50% rc	.11	.18
SOYBEANS		
B, RdL, spring TP, conv	0.48	0.54
C-B, TP annually, conv	.43	.51
B, no-till pl	.22	.28
C-B, no-till pl, fall shred C stalks	.18	.22
WHEAT		
W-F, fall TP after W	0.38	
W-F, stubble mulch, 500 lbs rc	.32	
W-F, stubble mulch, 1000 lbs rc	.21	

Abbreviations defined:

B - soybeans
C - corn
c-k - chemically killed
conv - conventional
cot - cotton
F - fallow
M - grass & legume hay
pl - plant
W - wheat
wc - winter cover

lbs rc - pounds of crop residue per acre remaining on surface after new crop seeding
% rc - percentage of soil surface covered by residue mulch after new crop seeding
70-50% rc - 70% cover for C values in first column; 50% for second column
RdR - residues (corn stover, straw, etc.) removed or burned
RdL - all residues left on field (on surface or incorporated)
TP - turn plowed (upper 5 or more inches of soil inverted, covering residues)

from reference 1

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are listed in Table 8. These values are based on rather limited field data, but P has a narrower range of possible values than the other five factors.

TABLE 8. VALUES OF FACTOR P[11]

Practice	Land slope (percent)				
	1.1-2	2.1-7	7.1-12	12.1-18	18.1-24
	(Factor P)				
Contouring (P_c)	0.60	0.50	0.60	0.80	0.90
Contour strip cropping (P_{sc})					
R-R-M-M[1]	0.30	0.25	0.30	0.40	0.45
R-W-M-M	0.30	0.25	0.30	0.40	0.45
R-R-W-M	0.45	0.38	0.45	0.60	0.68
R-W	0.52	0.44	0.52	0.70	0.90
R-O	0.60	0.50	0.60	0.80	0.90
Contour listing or ridge planting (P_{cl})	0.30	0.25	0.30	0.40	0.45
Contour terracing (P_t)[2]	[3] $0.6/\sqrt{n}$	$0.5/\sqrt{n}$	$0.6/\sqrt{n}$	$0.8/\sqrt{n}$	$0.9/\sqrt{n}$
No support practice	1.0	1.0	1.0	1.0	1.0

[1] R = rowcrop, W = fall-seeded grain, O = spring-seeded grain, M = meadow. The crops are grown in rotation and so arranged on the field that rowcrop strips are always separated by a meadow or winter-grain strip.
[2] These P_t values estimate the amount of soil eroded to the terrace channels and are used for conservation planning. For prediction of off-field sediment, the P_t values are multiplied by 0.2.
[3] n = number of approximately equal-length intervals into which the field slope is divided by the terraces. Tillage operations must be parallel to the terraces.

Example: An owner/operator proposes to close one section of his small landfill with a sandy clay subsoil cover having the surface configuration shown in Figure 21. The factor R has been established as 200 for this locality. The evaluator questions anticipated erosion along the steep side and assigns the following values to the other factors in the USLE after inspecting Tables 5 through 8:

$$K = 0.14 \quad LS = 8.3 \quad C = 1.00 \quad P = 0.90$$

The rate of erosion for the steep slope of the landfill is calculated as follows:

$$A = 200\ (0.14\ \text{tons/acre})\ (8.3)\ (1.00)\ (0.90) = 209\ \text{tons/acre}$$

This erosion not only exceeds a limit recommended by the permitting authority but also indicates a potential

from reference 1

APPENDIX 12-E

Settlement Calculations

One-Dimensional Calculations

SETTLEMENT OF HIDE PILES

OBJECTIVE: ESTIMATE SETTLEMENTS AND MAXIMUM DIFFERENTIAL SETTLEMENTS OF HIDE PILES TO ENSURE ADEQUATE DRAINAGE GRADIENTS.

ASSUMPTIONS:

1. WORST CASE IS AT RELATIVELY FLAT CREST OF PILE.

2. UNIFORM STRESS INCREMENT THROUGHOUT SURFICIAL MATERIALS AND FILL AND HIDE RESIDUE (VALID FOR WIDE LOAD).

CALCULATIONS:

1. MAXIMUM THICKNESS OF FILL & HIDE RESIDUE = 35 ft
2. MAXIMUM RATE OF CHANGE OF THICKNESS = 3 ft in 100 linear ft.
3. MAXIMUM THICKNESS OF SURFICIAL MATERIAL = 4 ft

SECTION E-E' FIG. 6-2

LOADING:

IMPERMEABLE CAP = 3 ft x 120 pcf = 360 psf
BACKFILL (max) = 3 ft x 125 pcf = 375 psf

735 psf

$$\text{SETTLEMENT} = \Delta S = C_c H/(1+e_o) \left(\log \frac{p_o' + \Delta q}{p_o'}\right)$$

WHERE

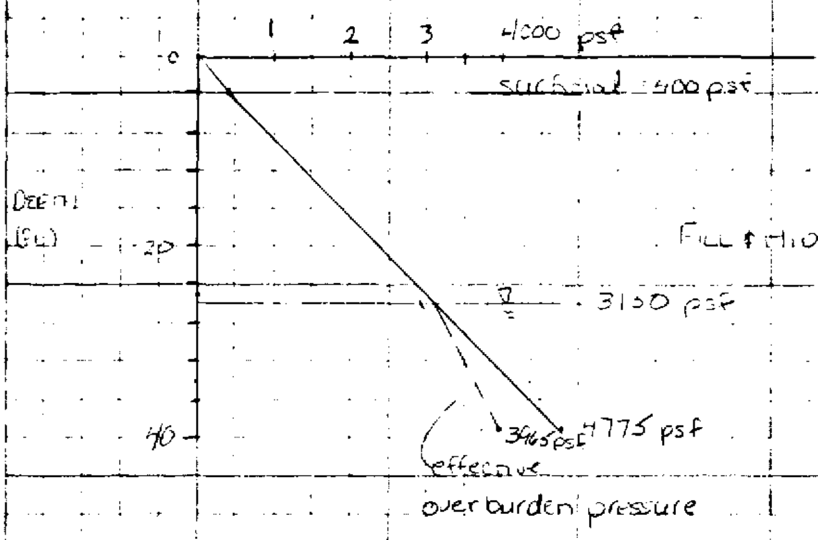
C_c = compression index
e_o = initial void ratio
H = layer thickness
P_o = overburden pressure
Δq = stress increment

FROM TASK S-2 REPORT (GOLDER ASSOCIATES, 1990)

SURFICIAL MATERIALS : $C_c = 0.50$
$e_o = 1.5$

FILL & HIDE RESIDUE $C_c = 0.30$
$e_o = 0.76 \rightarrow 1.55$; [illegible] = 1.10

OVERBURDEN PRESSURE



CASE 1 - MAX HEIGHT OF HIDE & RESIDUE = 35'

	C_c	H	e_o	p_o'	Δq	Δs (ft)
SURFICIAL	0.5	4	1.5	200	735	0.54
FILL & HIDE (ABOVE WT)	0.3	22	1.1	1775	735	0.47
FILL & HIDE (BELOW WT)	0.3	13	1.1	3560	735	0.15
						1.16 (ft)

CASE 2 - HEIGHT OF HIDE & RESIDUE = 32'

	C_c	H	e_o	p_o'	Δq	Δs (ft)
SURFICIAL	0.5	4	1.5	200	735	0.54
FILL & HIDE (ABOVE WT)	0.3	20	1.1	1650	735	0.46
FILL & HIDE (BELOW WT)	0.3	12	1.1	3275	735	0.15
						1.15 ft

Golder Associates

SUBJECT Impermeable [illegible]
Job No. [illegible]
Ref. 1527
Made by FAC
Checked [illegible]
Reviewed [illegible]
Date [illegible]/26/90
Sheet 3 of 3

DIFFERENTIAL SETTLEMENT

$= 1.16\text{ ft} - 1.15\text{ ft} = 0.01\text{ ft}$ in 100 ft

$= 0.01\ \%$

∴ 5% grades are not materially affected by max possible differential settlement.

Schmertmann Method

Golder Associates	SUBJECT SETTLEMENT CALCULATIONS - EPA COMMENT RESPONSE - [illegible] 3 [illegible] DESIGN		
	Job No. 903-6400	Made by PAC	Date 1/18/91
	Ref. EAST HIDE PILE	Checked [illegible]	Sheet 1 of 16
		Reviewed [illegible]	

OBJECTIVE: TO DETERMINE THE AMOUNT OF DIFFERENTIAL SETTLEMENT OF THE EAST HIDE PILE USING THE SCHMERTMANN METHOD BASED ON STANDARD PENETRATION RESISTANCE.

ASSUMPTIONS:

1) USE TWO EXTREME PDI BOREHOLES LOCATED AT THE CREST OF THE EAST HIDE PILE: BOREHOLES 12 & 13.

2) USE SCHMERTMANN METHOD ASSUMING AN AXISYMMETRIC LOADING.

3) USE SIEVE ANALYSIS RESULTS FROM PDI TASK S-2, INTERIM FINAL REPORT TO DETERMINE D_{50}.

4) MAXIMUM STRESS INCREMENT Δp DUE TO THE COVER AND MAX. FILL THICKNESS

REFERENCES:

1) "IMPROVED STRAIN INFLUENCE FACTOR DIAGRAMS," JOHN H SCHMERTMANN, JOHN PAUL HARTMAN AND PHILLIP R BROWN, AUGUST 1978.

2) "SPT-CPT CORRELATIONS", ROBERTSON, CAMPANELLA, AND WIGHTMAN, 1984

3) "STATIC CONE TO COMPUTE STATIC SETTLEMENT OVER SAND," SCHMERTMANN, 1970.

4) PRE-DESIGN INVESTIGATION TASK S-2 STABILITY OF HIDE PILES, INTERIM FINAL REPORT, GOLDER ASSOCIATES INC., 1990.

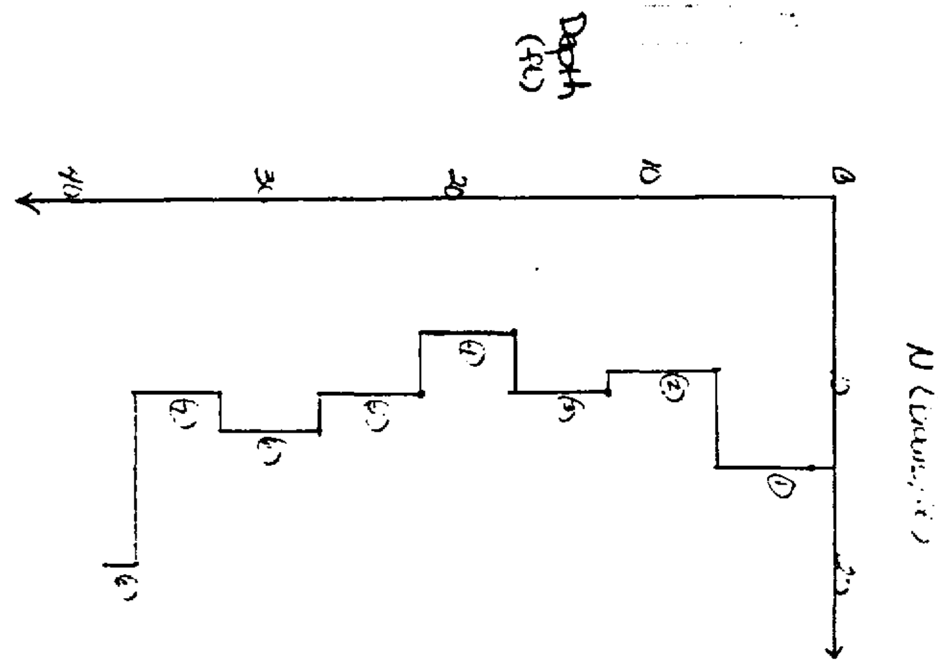
CALCULATIONS:

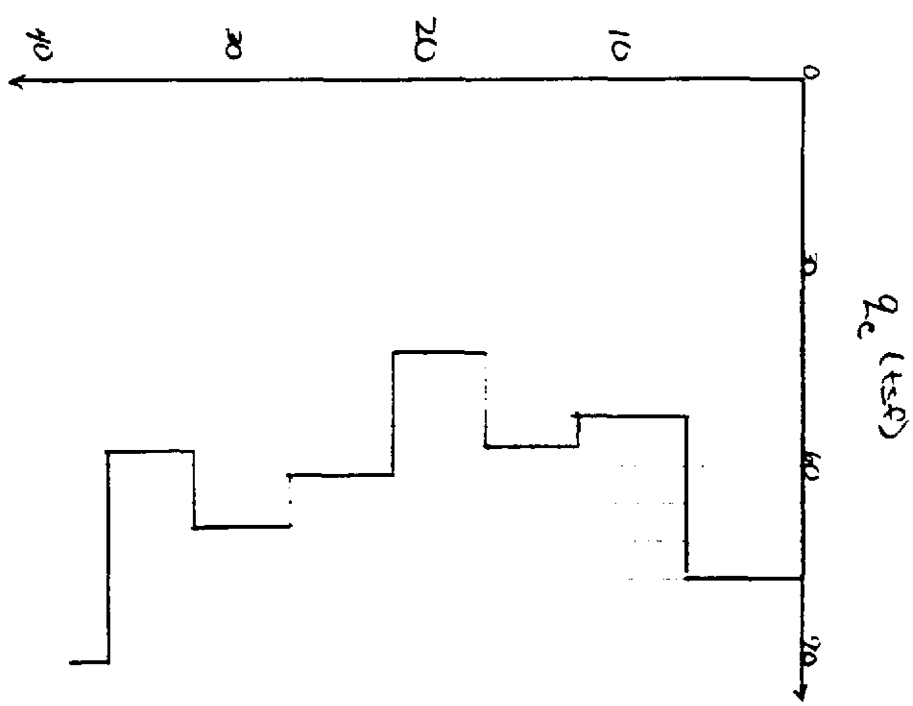
SEE ATTACHED PAGES

Golder Associates

SUBJECT Settlement Calculations FHP		
Job No. 903-6400	Made by RAC	Date 1/17/91
Ref.	Checked	Sheet 2 of 16
	Reviewed	

BOREHOLE #12





Golder Associates	SUBJECT SETTLEMENT CALCULATIONS EHP		
	Job No. 923-6400 Ref.	Made by GAR Checked VEST Reviewed PCR	Date 1/17/91 Sheet 3 of 16

BOREHOLE #12

LAYER	SAMPLE ID	D_{50}	N	q_c/N *	q_c	$E = 2.5 q_c$ Δ
1	Surficial Mat'l	0.35	14	5.6	78.4	196
2	ST-1	0.38	9	5.8	52	129
3	Fill & Hide Residue #10 S-1	0.35	10	5.6	56	140
4	ST-2	0.51	7	6.2	43.4	108.5
5	ST-2	0.51	10	6.2	62	155
6	Fill & Hide Residue #10, S-5	0.38	12	5.8	70	174
7	Fill & Hide Residue #10 S-5	0.38	10	5.8	58	175
8	Fill & Hide Residue #10 ST-4	0.22	19	4.8	91.2	228

* Robertson & CAMPANELLA (1984)
Δ Schmertmann (1978)

CALCULATE I_{zp} according to Schmertmann (1978)

$$I_{zp} = 0.5 + 0.1 \left(\frac{\Delta p}{\sigma_{zp}}\right)^{1/2}$$

$$\Delta p = \gamma_{cover} \times t_{cover} + \gamma_{fill} \times t_{fill}$$

$$= (120\,pcf)(3ft) + (125\,pcf)(3ft)$$
$$\sim 735\ psf$$

σ'_{zp} @ $B/2$

Assume axisymmetric

$B = 325$ ft (avg value of length & width of crest of EHP)

$B/2 \sim 162.5$ ft

Golder Associates	SUBJECT: Settlement Calculations (EHP)
Job No. 903-6400 Ref.	Made by JJC Checked VAT Reviewed [illegible]
Date 1/17/91	Sheet 4 of 16

BOREHOLE #12

0
SURFICIAL MATERIAL $\gamma = 100$ pcf

FILL & HWC Residue $\gamma = 125$ pcf

20

WATER TABLE

40 OUTWASH SAND $\gamma = 120$ pcf

GLACIAL TILL $\gamma = 125$ pcf

BEDROCK $\gamma = 150$ pcf

BEDROCK @ EL 58 SECTION F-F' PDI TASK 5-2

60

$$\sigma'_{zp} = 100(2.5) + (125)(23.5) + (125-62.4)(7.5) + (120-62.4)(9) + (125-62.4)(8) + (150-62.4)(112.5)$$

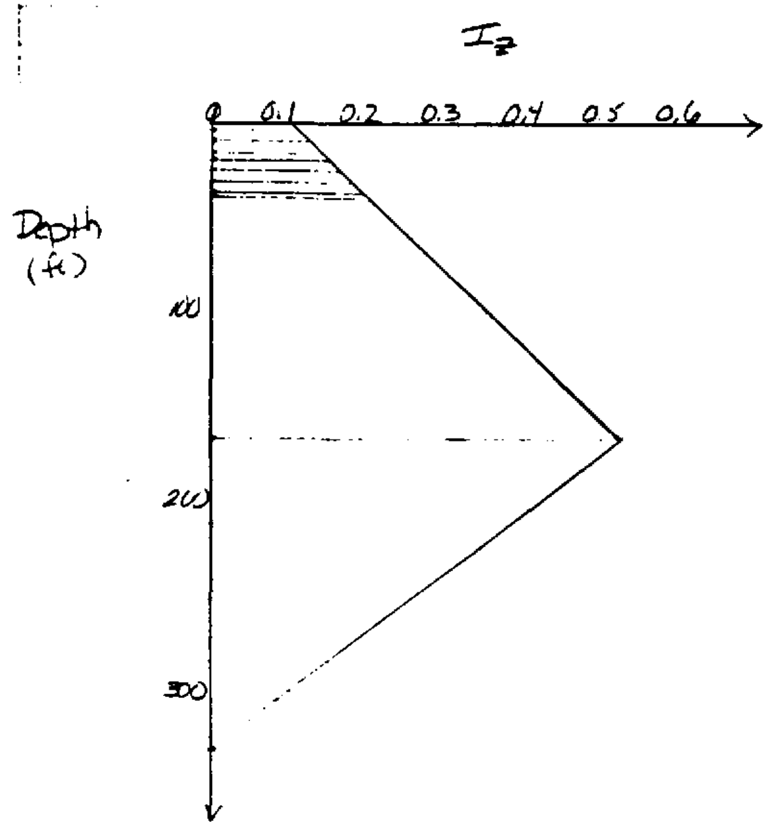
$$= 14{,}531.2 \text{ psf}$$

$$I_{zp} = 0.5 + 0.1\left(\frac{735}{14531}\right)^{1/2}$$

$$= 0.52$$

Golder Associates	SUBJECT Settlement Calculations (EHP)		
	Job No. 903-6408	Made by RAC	Date 1/17/91
	Ref.	Checked VSS7	Sheet 5 of 16
		Reviewed MR	

BOREHOLE #12



LAYER	Δz	q_c	E	DEPTH TO CENTER BELOW GROUND SURFACE	I_z	$(\frac{I_z}{E})\Delta z$
1	6	78.4	196	3	0.11	0.0034
2	5.5	52	129	8.75	0.125	0.0053
3	5	56	140	14	0.14	0.005
4	4.5	43.4	108.5	18.75	0.15	0.0062
5	5.5	62	155	23.75	0.165	0.0058
6	5	70	174	29	0.18	0.0052
7	5.5	58	145	34.25	0.195	0.0074
8	1.3	91.2	228	36.7	0.2	0.0011
					$\Sigma (\frac{I_z}{E})\Delta z$	0.0394

Golder Associates	SUBJECT Settlement Calculations (EHP)		
	Job No. 903-6400	Made by RPC	Date 1/7/90
	Ref.	Checked V497	Sheet 6 of 16
		Reviewed [illegible]	

BOREHOLE #12

$$S_d = C_1 C_2 \Delta p \Sigma \left(\frac{I_z}{E}\right)_i \Delta z_i \qquad \text{Schmertmann (1970)}$$

$$C_1 = 1.0 - 0.5(\sigma_0'/\Delta p) \geq 0.5$$

C_1 IS AN EMBEDDMENT CORRECTION FACTOR. IT IS CONSERVATIVE TO TAKE $C_1 = 1$

$$C_2 = 1 + 0.2 \log_{10}\left(\frac{t}{0.1}\right) \qquad t = 30 \text{ years}$$

$$= 1 + 0.2 \log\left(\frac{30}{0.1}\right)$$

$$= 1.5$$

$$\Delta p = 735 \text{ psf}$$

$$S_d = (1)(1.5)(735 \text{ psf} \cdot \tfrac{[illegible]}{[illegible]})(0.0394)$$

$$= 0.0217 \text{ ft} = 0.26 \text{ in}$$

RECORD OF BOREHOLE 12

PROJECT: INDUSTRI-PLEX
PROJECT LOCATION: WOBURN
PROJECT NUMBER: 893-6255

BORING DATE: 06/25/90
BORING LOCATION: N: 554,627
E: 696,263

SHEET: 1 OF 1
DATUM: MSL

DEPTH & FEET	BORING METHOD	SOIL PROFILE: DESCRIPTION	USCS	GRAPHIC LOG	ELEV / DEPTH	SAMPLES: NUMBER	TYPE	BLOWS / 6 in	N	REC/ATT	PENETRATION RESISTANCE BLOWS/FT ■ (10 20 30 40 50 60 70 80 90); WATER CONTENT, PERCENT Wp ⊢ W ⊣ Wl (10 20 30 40 50 60 70 80 90)	PIEZOMETER OR STANDPIPE INSTALLATION
0					108.10 / 0.00							
		0.0-2.5 ft. Compact, moderate to dusky brown, f-SAND, some silt, few roots, possible hairs, (SM). FILL	SM			1	DO	2,5,9,5	14	70		
					105.60 / 2.50							
		2.5-36.9 ft. Compact, black with occasional light-gray patches, m-f SAND, little to some silt to clayey silt, hair and hair clumps, few micas, occasional clumps of root mass, (SM to SP-SM). FILL AND HIDE RESIDUE. Sample saturated at 30.5 ft. Water level at approximately 26.0 ft. after hole stood for 2 days.				ST-1	TO	SHELBY TUBE		90		
5						2	DO	4,5,4,4	9	80		
10						3	DO	5,5,5,6	10	100		
15						4	DO	2,3,4,4	7	100		
						ST-2	TO	SHELBY TUBE		100		
20						5	DO	6,5,5,5	10	80		
25						6	DO	27,5,7,7	12	25		
30						7	DO	2,4,6,8	10	100		
35						8	DO	7,8,11,21	19	75		
		OUTWASH SAND			71.20 / 70.80 / 37.30							
		AUGER REFUSAL AT 37.3 FT. BELOW GROUND SURFACE.										
40												

DRILL RIG: Mobile B-57 ATV
DRILLING CONTRACTOR: Geologic
DRILLER: T. Paquette

Golder Associates

LOGGED: RJI
CHECKED: JEW
DATE: 06/31/90

7/16

FROM KASIM, et.al (1986)

... data is shown in Table 1. Impurities such as clay lumps or ...tonite "driller's mud" were removed before performing the tests. It is to be noted that from both this study and studies made for other nearby portions of the greater project site, the percentage fines for the hydraulic fill sand is typically about 10, whereas the natural sand typically has about 20% fines content.

Occasionally, blow counts were not included in the correlation be-

TABLE 2.—Penetration Data

Depth (ft)[a] (1)	Measured N[b] (2)	Corrected N (3)	q_c (kg/cm²) (4)	Depth (ft)[a] (5)	Measured N[b] (6)	Corrected N (7)	q_c (kg/cm²) (8)
(a) Test Location 1				(e) Test Location 5			
3	25	25	106	3	19	19	115
5	27	27	133	6(7)	9	9	39
8	28	28	119	33.2*	40	40	88
14.6	26	26	113	(f) Test Location 6			
27.1	6	6	41	3	31(1)	41.3	236
34.2*	10	10	60	6	26(1)	34.7	142
37.2*	53	53	186	9(8)	22(1)	29.3	96
(b) Test Location 2				35.7*	40(1)	54.7	180
2	29	29	126	(g) Test Location 7			
5	42	42	271	3	34(1)	45.3	234
8	31	31	186	6	39(1)	52	286
11.1	18	18	105	9	40(1)	53.3	295
14.1	21	21	79	12.1	47(1)	62.7	282
17.1	8	8	50	18.1(9)	15(1)	20	71
20.6*	9	9	30	21.1*	5(1)	6.7	39
31.2*	24	24	54	24.1*	18(1)	24	171
34.2*	31	31	110	(h) Test Location 8			
(c) Test Location 3				2.3(10)	17(1)	22.7	153
3	30	30	132	3.5	33(1)	44	230
6(1)	47	47	188	8.5	43(1)	57.3	220
9	26	26	133	11.6	56	56	200
12	19	19	76	17.6	12(1)	16	42
15.1(2)	7	7	38	20.6*	5(1)	6.7	67
18.1(3)	2	2	4	23.6*(11)	13(1)	17.3	76
33.2*(4)	4	4	9	26.6*	9(1)	12	241
37.2*	27	27	67	(i) Test Location 9			
(d) Test Location 4				6.5	21(2)	35	139
3	12	12	60	7.6	32(2)	53.3	85
6	28	28	155	9.3	19(2)	31.7	79
9	25	25	157	10.7	6(2)	10	63
12(5)	19	19	79	13.2	23(2)	38.3	100
15.1	30	30	165	17.2(12)	13(2)	21.7	116
29.2*(6)	26	26	66	19.2*	11(2)	18.3	47
34.2*	40	40	130	20.7*(13)	16(2)	26.7	75
39.2*	31	32	196	23.2*	28(2)	46.7	172
				31.2*	25(2)	41.7	107
				41.3(14)	10(2)	16.7	60

[a]Depth is to midpoint of SPT. An asterisk (*) next to depth denotes natural sand, otherwise material is hydraulic fill sand. A number in parentheses next to depth is the sample number for grain size analyses, which are summarized in Table 1.

[b]SPT procedure: SPT conducted with safety hammer and three wraps. N corresponds to the standard energy (60%). (1) SPT conducted with safety hammer and two wraps. N corrected to the standard donut hammer and two wraps according to Kovacs; or (2) SPT conducted using no liner for sampler to be used with liner, safety hammer and two wraps used; N value corrected according to Kovacs, et al.

BOREHOLE #12

cause the encountered conditions were considered to in...date the test results, such as changes in material types discovered during the penetration test. A total of 65 test data points were selected for the correlations. A summary of the field measurements is given in Table 2.

ANALYSIS

The correlation between q_c and N was made by averaging q_c over the same 12-in. (30-cm) length as the N values were recorded, i.e., from the 6-in. (15-cm) to the 18-in. (30-cm) penetration levels of the sampler.

The data resulting from this work was expressed in terms of q_c/N versus the mean grain diameter and was superimposed on the average curve and data points (solid circles) by Robertson and Campanella (3), as shown in Fig. 1. The data points from this work are denoted by open circles and triangles for the hydraulic and natural sands, respectively, and are indexed by q_c in kg/cm² (see Tables 1 and 2).

Examination of the relationship in Fig. 1 shows that although the Robertson and Campanella (3) curve represents a good average for the study site, significant scatter around the mean curve is evident. Such scatter could indicate either that correlation relationships are difficult to obtain because of inherent variabilities in both types of tests or that the effect of some other soil property that is not completely defined by the mean grain diameter. The entire data bank in Table 2 was analyzed to investigate the possible dependence of the q_c/N on the numerical value of q_c. The results were inconclusive.

Another plot was developed to evaluate the possible dependence of q_c/N on the fines content. For that purpose, we have utilized only that

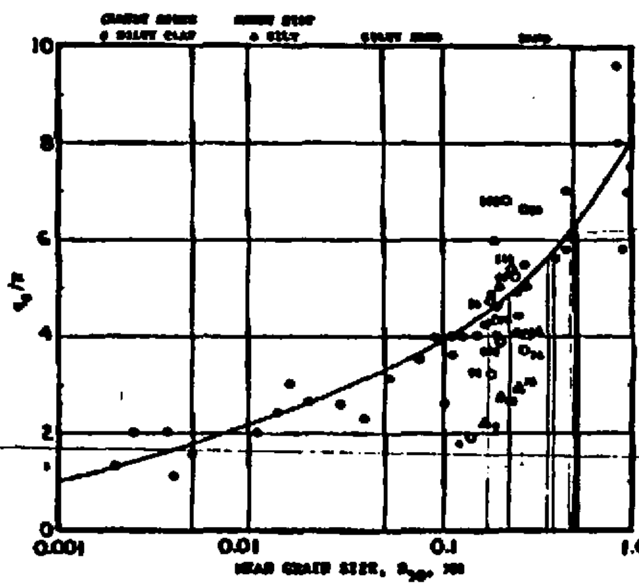
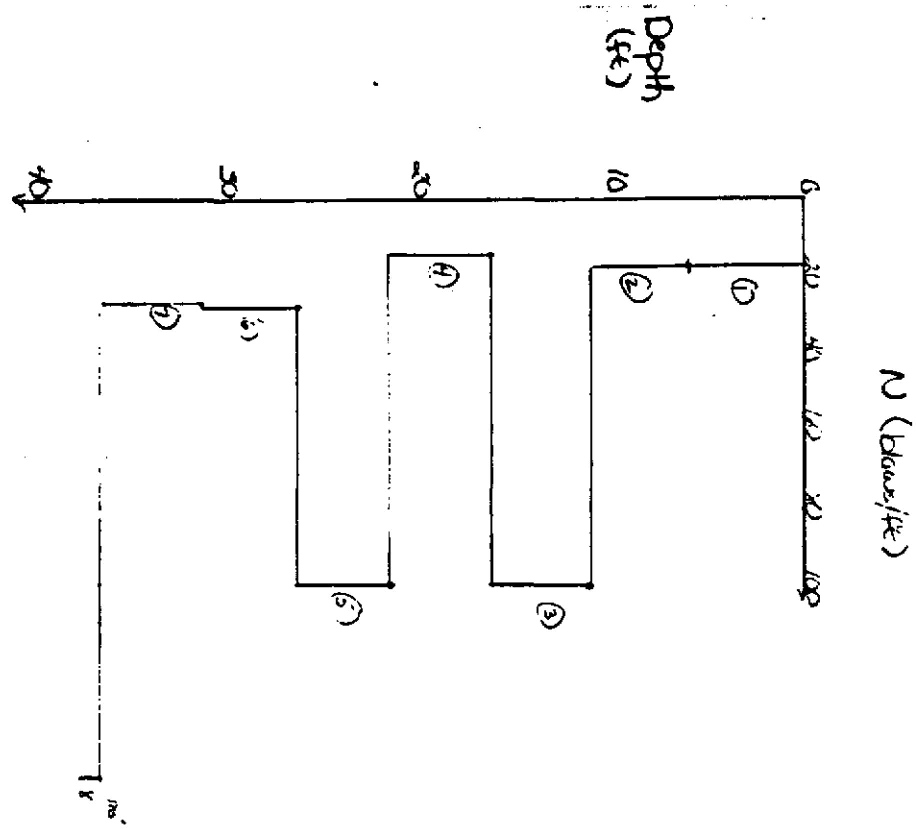


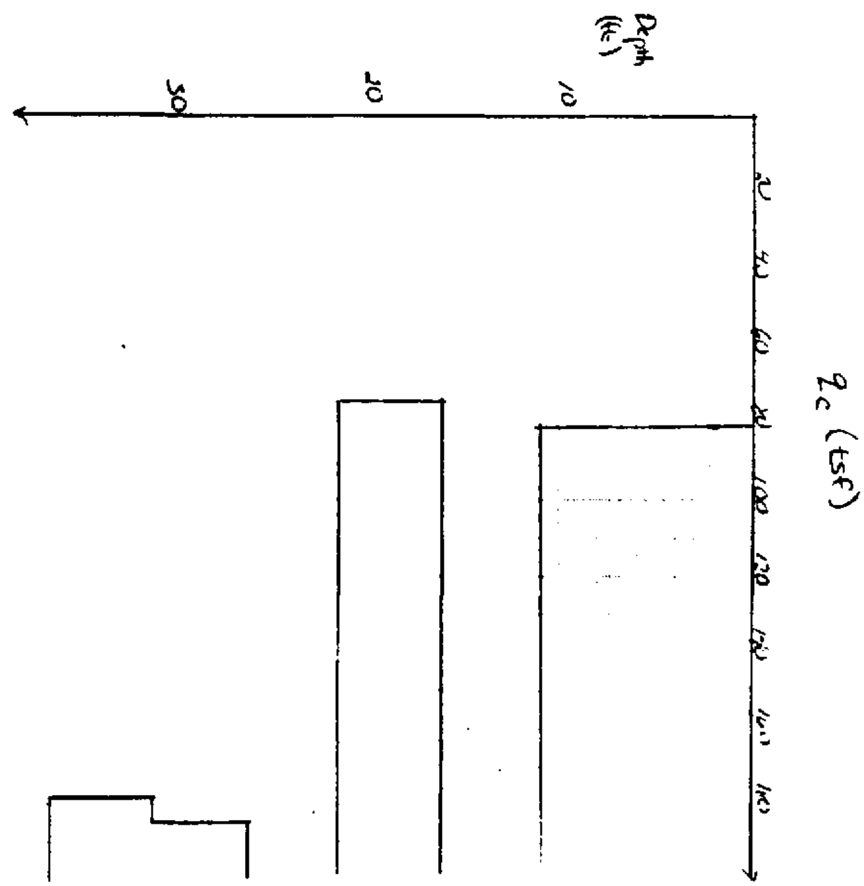
FIG. 1.—Variation of q_c/N with Mean Grain Size

9/18

Golder Associates	SUBJECT Settlement Calculations EHP		
	Job No. 903-6460	Made by RAC	Date 1/17/91
	Ref.	Checked UE27	Sheet 9 of 16
		Reviewed	

BOREHOLE #13





Golder Associates	SUBJECT Settlement Calculations (EHP)		
	Job No. 903-6400 Ref.	Made by RAC Checked VE&T Reviewed RER	Date 1/17/91 Sheet 10 of 10

BOREHOLE #13

LAYER	SAMPLE ID	D_{50}	N	q_c/N *	q_c	$E = 2.5 q_c$ ▲
1	S-2	0.2	17	4.8	81.6	204
2	S-2	0.2	17	4.8	81.6	204
3	—	—	>100	—	—	—
4	ST-2	0.35	14	5.6	78.4	196
5	—	—	>100	—	—	—
6	BH-13 Bulk	0.58	28	6.6	184.8	462
7	BH13 Bulk	0.58	27	6.6	178.2	445.5
8	—	—	185	—	—	—

* Robertson and Companella (1984)
▲ Schmertmann (1978)

Calculate I_{zp} according to Schmertmann (1978)

$$I_{zp} = 0.5 + 0.1 \left(\frac{\Delta p}{\sigma'_{zp}}\right)^{1/2}$$

$$\Delta p = \gamma_{cover} \times t_{cover} + \gamma_{fill} \times t_{fill}$$

$$= 120\,pcf(3) + (125)\times(3)$$
$$= 735\,psf$$

σ'_{zp} @ $B/2$

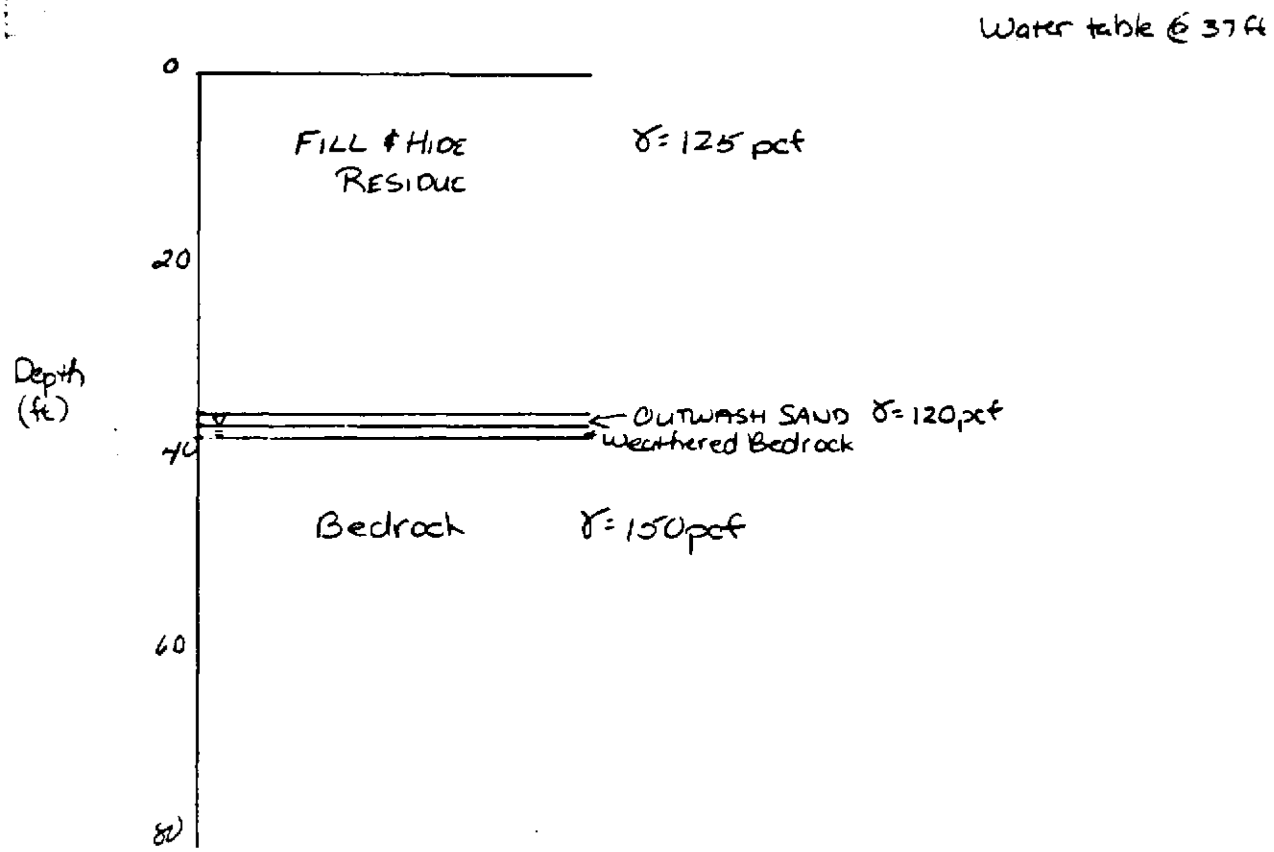
Assume axisymmetric
$B = 325$ ft (avg. of length and width of crest of EHP)

$B/2 = 162.5$ ft.

Golder Associates

SUBJECT Settlement Calculations (EHP)		
Job No. 903-6700	Made by RAC	Date 1/17/91
Ref.	Checked VEE7	Sheet 11 of 16
	Reviewed	

BOREHOLE #13



$$\sigma_{zp}' = 125\,pcf(35.5\,ft) + 120\,pcf(0.7\,ft) + (150 - 62.4\,pcf)(125.5\,ft)$$

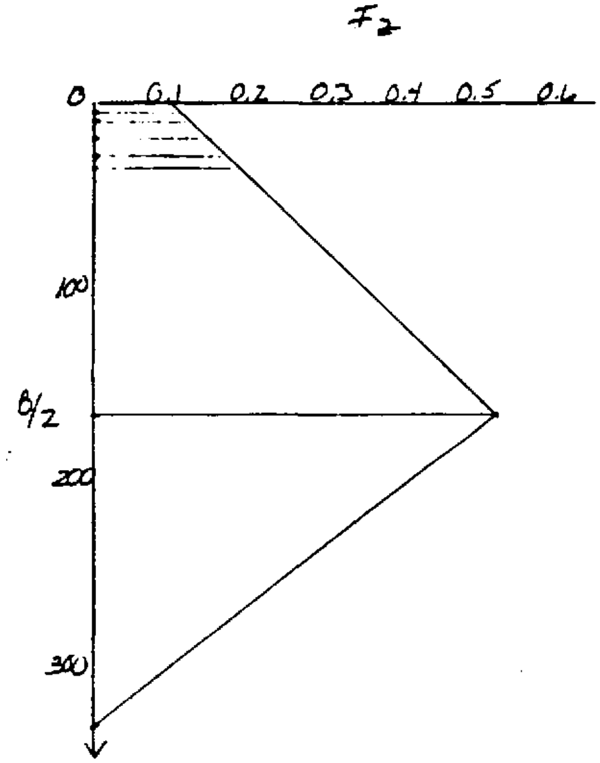
$$= 15515\,psf$$

$$I_{zp} = 0.5 + 0.1\left(\frac{735}{15515}\right)^{1/2}$$

$$= 0.52$$

Golder Associates	SUBJECT Settlement Calculations		
	Job No. 903-6400	Made by RAC	Date 1/17/90
	Ref.	Checked VEL7	Sheet 12 of 16
		Reviewed [illegible]	

Borehole #13



LAYER	Δz	q_c	E	Depth to Center Below Grd. Surface	I_z	$(\frac{I_z}{E})\Delta z$
1	6	81.6	204	3	0.11	0.0032
2	5	81.6	204	8.5	0.125	0.003
3	5	*Assume Incompressible *(conservative for differential settlement calculation)		—	—	0
4	5	78	196	18.5	0.15	0.0038
5	5	*Assume Incompressible		—	—	—
6	5	184.8	462	28.5	0.175	0.0019
7	5.2	178.2	445.5	33.6	0.19	0.0022
8	0.8	*Assume Incompressible		—	—	—

$\Sigma (\frac{I_z}{E})\Delta z$ 0.0141

Golder Associates	SUBJECT Settlement Calculations (EHP)		
	Job No. 903-6400 Ref.	Made by PAC Checked U9E7 Reviewed [signature]	Date 1/17/91 Sheet 13 of 16

BOREHOLE #13

$$S_d = C_1 C_2 \Delta p \sum \left(\frac{I_z}{E}\right) \Delta z$$ Schmertmann (1970)

$$C_1 = 1 - 0.5\left(\frac{\sigma_0'}{\Delta p}\right) \geq 0.5$$

C_1 IS AN EMBEDMENT CORRECTION FACTOR. IT IS CONSERVATIVE TO TAKE $C_1 = 1$

$$C_2 = 1 + 0.2 \log_{10}\left(\frac{t}{0.1}\right)$$ $t = 30$ years

$$= 1 + 0.2 \log_{10}\left(\frac{30}{0.1}\right)$$

$$= 1.5$$

$$S_d = (1)(1.5)\left(735 \text{ psf} \times \frac{\text{ton}}{2000 \text{ lb}}\right)(0.0141)$$

$$= 0.0078 \text{ ft} = 0.094 \text{ in}$$

PROJECT: INDUSTRI-PLEX

PROJECT LOCATION: WOBURN

PROJECT NUMBER: 893-6255

RECORD OF BOREHOLE 13

BORING DATE: 05/29/90

BORING LOCATION: N: 554,730 E: 696,356

SHEET: 1 OF 1

DATUM: MSL

14/16

DEPTH SCALE FEET	SOIL PROFILE – DESCRIPTION	USCS	ELEV / DEPTH	SAMPLES – NUMBER	TYPE	BLOWS / 6 in	N	REC/ATT
0			109.10					
	0.0-35.5 ft. Compact, black with occasional light-gray pockets, f-SAND, little to some silt to clayey silt, few cobbles and f-gravel, hair and hair clumps, occasional clumps of root mass, (SM to SP-SM). FILL AND HIDE RESIDUE. Water encountered at approximately 37.0 ft. at end of drilling.	SM to SP-SM	0.00	1	DO	2,7,10,21	17	75
5				2	DO	8,8,8,7	17	80
				ST-1	TO	SHELBY TUBE		30
10				3	DO	8,100/.1'	>100	83
15				4	DO	5,7,7,7	14	70
				ST-2	TO	SHELBY TUBE		80
20				5	DO	100/0'	>100	0
25				6	DO	11,13,15,20	28	60
30				7	DO	8,14,13,23	27	100
	NOTES: 1.) Recovered shelby tube sample placed in jar to TO-1.							
35	35.5-36.2 ft. Dense, black, m-f SAND, little f-gravel, trace silt, possible few hairs, (SP). OUTWASH SAND ?	SP	73.60 / 35.50	8	DO	18,60,125	185	100
	36.2-37.0 ft. Weathered bedrock.		72.90 / 36.20					
	BORING TERMINATED AT 37.0 FT. BELOW GROUND SURFACE.		72.10 / 37.00					
40								

PENETRATION RESISTANCE BLOWS/FT ■ 10 20 30 40 50 60 70 80 90

WATER CONTENT, PERCENT Wp W Wl 10 20 30 40 50 60 70 80 90

PIEZOMETER OR STANDPIPE INSTALLATION

DRILL RIG: Mobile B-57 ATV

DRILLING CONTRACTOR: Geologic

DRILLER: T. Paquette

Golder Associates

LOGGED: RJI

CHECKED: JEW

DATE: 05/31/90

15/16

DH #13

…asic data is shown in Table 1. Impurities such as clay lumps or …ntonite "driller's mud" were removed before performing the tests. It is to be noted that from both this study and studies made for other nearby portions of the greater project site, the percentage fines for the hydraulic fill sand is typically about 10, whereas the natural sand typically has about 20% fines content.

Occasionally, blow counts were not included in the correlation because the encountered conditions were considered to invalidate the test results, such as changes in material types discovered during the penetration test. A total of 65 test data points were selected for the correlations. A summary of the field measurements is given in Table 2.

TABLE 2.—Penetration Data

Depth (ft)[a] (1)	Measured N^b (2)	Corrected N (3)	q_c (kg/cm²) (4)	Depth (ft)[a] (5)	Measured N^b (6)	Corrected N (7)	q_c (kg/cm²) (8)
(a) Test Location 1				(e) Test Location 5			
3	25	25	106	3	19	19	116
5	27	27	123	6(7)	9	9	39
8	28	28	139	28.2*	40	40	88
14.6	26	26	113	(f) Test Location 6			
17.1	6	6	40	3	31(1)	41.3	236
24.2*	10	10	40	6	26(1)	34.7	142
27.2*	53	53	186	9(8)	22(1)	29.3	96
(b) Test Location 2				35.2*	41(1)	54.7	180
2	29	29	226	(g) Test Location 7			
5	62	62	271	3	34(1)	45.3	256
8	32	32	186	6	39(1)	52	285
11.1	18	18	188	9	40(1)	53.3	288
14.1	21	21	79	12.1	47(1)	62.7	242
17.1	8	8	30	18.1(9)	15(1)	20	76
20.6*	9	9	30	21.1*	5(1)	6.7	30
30.2*	24	24	56	26.1*	18(1)	24	171
34.2*	31	31	136	(h) Test Location 8			
(c) Test Location 3				2.5(10)	17(1)	22.7	153
3	39	39	152	5.5	33(1)	44	230
6(1)	47	47	185	8.5	43(1)	57.3	230
9	36	36	139	11.6	56	56	300
12	19	19	76	17.6	12(1)	16	42
15.1(2)	7	7	30	20.6*	5(1)	6.7	17
18.1(3)	2	2	6	23.6*(11)	13(1)	17.3	76
33.2*(4)	4	4	9	26.6*	9(1)	12	241
37.2*	27	27	67	(i) Test Location 9			
(d) Test Location 4				6.1	21(2)	35	119
3	12	12	48	7.6	32(2)	53.3	86
6	28	28	155	9.1	19(2)	31.7	79
9	25	25	157	10.7	6(2)	10	63
12(5)	19	19	99	15.2	23(2)	38.3	188
15.1	30	30	165	17.3(12)	13(2)	21.7	116
29.2*(6)	26	26	66	19.2*	11(2)	18.3	47
34.2*	40	40	130	20.7*(13)	16(2)	26.7	75
38.2*	32	32	186	23.2*	28(2)	46.7	172
				31.2*	25(2)	41.7	107
				40.2(14)	10(2)	16.7	60

[a]Depth is to midpoint of SPT. An asterisk (*) next to depth denotes natural sand, otherwise material is hydraulic fill sand. A number in parentheses next to depth is the sample number for grain size analyses, which are contained in Table 1.

[b]SPT procedure: SPT conducted with safety hammer and three wraps. N corresponds to the standard energy (60%). (1) SPT conducted with safety hammer and two wraps. N corrected to the standard donut hammer and two wraps according to Kovacs; or (2) SPT conducted using no liners for sampler to be used with liners, safety hammer and two wraps used; N value corrected according to Kovacs, et al.

Analysis

The correlation between q_c and N was made by averaging q_c over the same 12-in. (30-cm) length as the N values were recorded, i.e., from the 6-in. (15-cm) to the 18-in. (30-cm) penetration levels of the sampler.

The data resulting from this work was expressed in terms of q_c/N versus the mean grain diameter and was superimposed on the average curve and data points (solid circles) by Robertson and Campanella (3), as shown in Fig. 1. The data points from this work are denoted by open circles and triangles for the hydraulic and natural sands, respectively, and are indexed by q_c in kg/cm² (see Tables 1 and 2).

Examination of the relationship in Fig. 1 shows that although the Robertson and Campanella (3) curve represents a good average for the study site, significant scatter around the mean curve is evident. Such scatter could indicate either that correlation relationships are difficult to obtain because of inherent variabilities in both types of tests or that the effect of some other soil property that is not completely defined by the mean grain diameter. The entire data bank in Table 2 was analyzed to investigate the possible dependence of the q_c/N on the numerical value of q_c. The results were inconclusive.

Another plot was developed to evaluate the possible dependence of q_c/N on the fines content. For that purpose, we have utilized only that

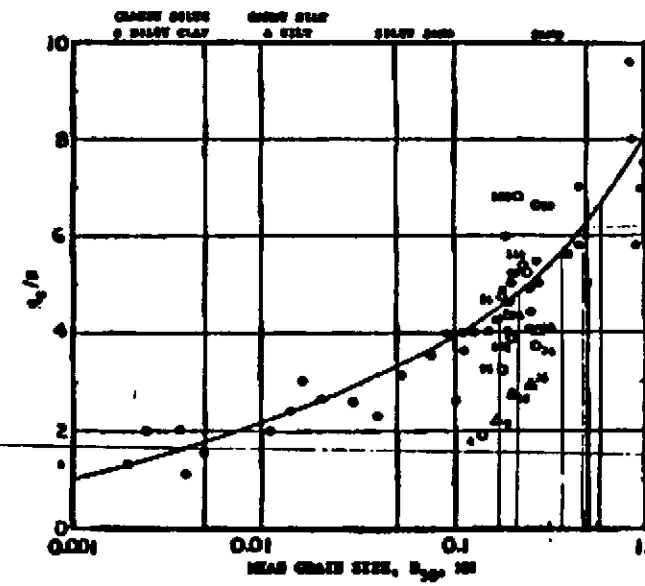


FIG. 1.—Variation of q_c/N with Mean Grain Size

RESULTS:

TOTAL DIFFERENTIAL SETTLEMENT OVER 30 YEARS FOR THE EAST HIDE PILE

BH12 - BH13
0.0217 ft - 0.0078 ft = 0.0139 ft
DISTANCE = 140'

PERCENT DIFFERENTIAL SETTLEMENT

0.0139 ft/140 ft = 0.0099 % = 0.01 %

APPENDIX 12-F

Drainage Layer Calculations

Golder Associates	SUBJECT HELP MODEL SIMULATIONS		
	Job No. 903-6400 Ref.	Made by RDS Checked [illegible] Reviewed [illegible]	Date 1-18/91 Sheet 1 of 23

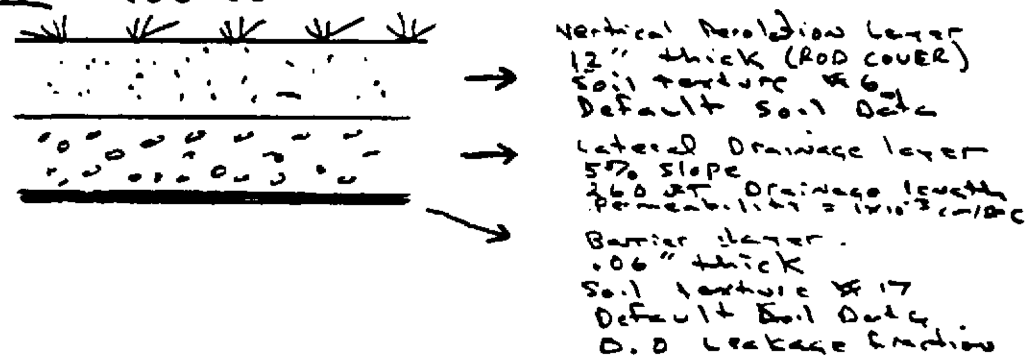
OBJECTIVE:

Model the East Hido pile drainage system using the HELP model to Determine the maximum head on the flexible membrane liner (FML). The head is required to remain below the ground surface to avoid ponding.

Methodology:

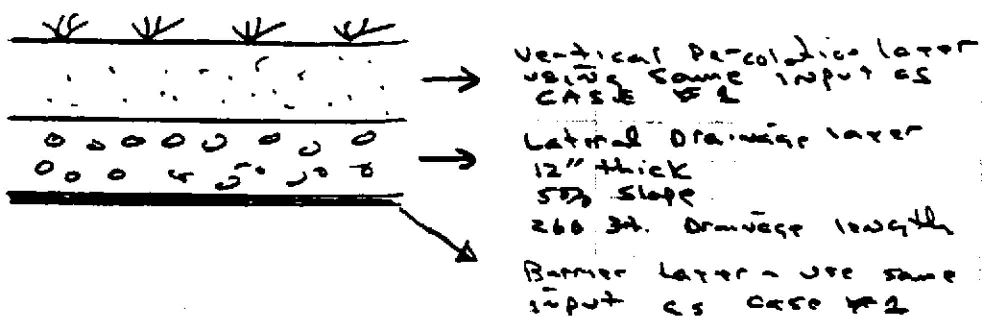
The Following cases are simulated:

CASE 1 - ROD cover



The model was run to determine the thickness of the drainage layer when the minimum ROD permeability of 1x10^-3 cm/sec is used. A 0.0 leakage fraction for the barrier layer was used for conservatism. Also, the minimum slope & maximum drainage length was also used for conservatism.

CASE 2



The model was run to determine the permeability needed for the drainage layer if the thickness in maintained at 12 inches.

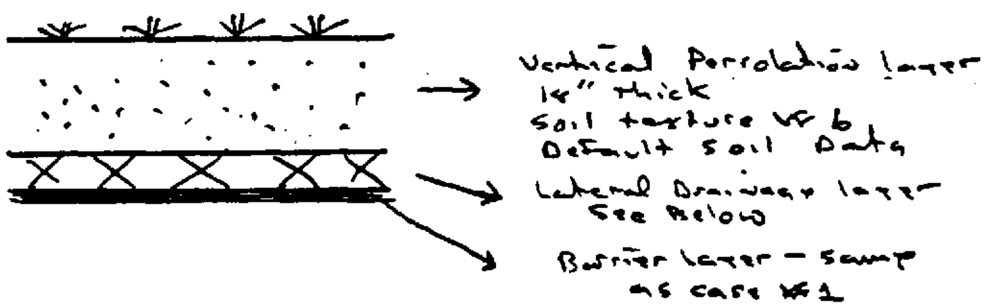
Results of Cases 1 & 2:

	Drainage layer permeability (cm/sec)	Thickness (IN)	Vert. Perc. Thickness (IN)	Head (IN above FML)
CASE 1	1×10^{-3}	102	12	107
CASE 2	5×10^{-2}	12	12	18.6

With a permeability of 1×10^{-3} cm/sec a drainage layer of 102 inches thick is required.
If the drainage layer is maintained at 12 inches thick, a permeability of about 5×10^{-2} cm/sec is required.

TRY A GEOCOMPOSITE:

CASE 3



The geocomposite will be modelled using published data for thickness & transmissivity from Geotechnical Fabrics Report (12/93) for TEX-NET.

Thickness (b) = 5.1 mm = .51 cm = .2 inches

$$\text{Transmissivity } (T) = .001 \text{ m}^2/\text{sec} = 10 \text{ cm}^2/\text{sec}$$

$$\text{IF} \quad T = K \times b \qquad K = T/b = \frac{10 \text{ cm}^2/\text{sec}}{.51 \text{ cm}} = 19.6 \text{ cm/sec}$$

OTHER INPUT PARAMETERS FOR GEOCOMPOSITE:

porosity = .8 vol/vol
wilting point = .02 vol/vol (lowest possible ...)
Field Capacity = .03 vol/vol (must be > wilting point)

The HELP model indicates a head on the FML of <u>10.5"</u>.

Conservatism was given to the slope length and leakage factor as discussed previously.

The vertical percolation was increased from the 12" (RED cover) to 18" to provide additional cover over the geocomposite

<u>CASE 4</u>

A simulation was run to model the geocomposite as a soil to check the result of CASE 3. The vertical percolation & barrier soil layer parameter remain the same as CASE 3.

Scale the soil thickness & permeability to equal the transmissivity of the geocomposite

use a thickness of 12" = 30.48 cm

$$T = Kb$$

$$K = \frac{T}{b} = \frac{10\ cm^2/sec}{30.48\ cm} = \underline{.328\ cm/sec}$$

The default soil data for type #1 was used for the other soil parameters.

The HELP model indicates a head on the FML of <u>5.0"</u>

Conservatism was given to slope length & leakage factor as previously discussed.

Golder Associates			
SUBJECT HELP MODEL Simulations			
Job No. 903-6402	Made by	Date 1-18-9	
Ref.	Checked	Sheet 4 of 23	
	Reviewed		

CONCLUSION:

Cases 1 and 2 indicate that a substantial thickness of soil or very high permeability is required to maintain a head below the ground surface with a granular drainage layer. A geocomposite maintains a head below the ground surface and has a minimal thickness.

5/23

TABLE 4. DEFAULT UNVEGETATED, UNCOMPACTED SOIL CHARACTERISTICS

SOIL TEXTURE HELP	USDA	USCS	POROSITY (VOL/VOL)	FIELD CAPACITY (VOL/VOL)	WILTING POINT (VOL/VOL)	SAT. HYD. CONDUCTIVITY (CM/SEC)
1	CoS	GS	0.417	0.045	0.018	1.0E-02
2	S	SW	0.437	0.062	0.024	5.8E-03
3	FS	SM	0.457	0.083	0.033	3.1E-03
4	LS	SM	0.437	0.105	0.047	1.7E-03
5	LFS	SM	0.457	0.131	0.058	1.0E-03
6	SL	SM	0.453	0.190	0.085	7.2E-04
7	FSL	SM	0.473	0.222	0.104	5.2E-04
8	L	ML	0.463	0.232	0.116	3.7E-04
9	SiL	ML	0.501	0.284	0.135	1.9E-04
10	SCL	SC	0.398	0.244	0.136	1.2E-04
11	CL	CL	0.464	0.310	0.187	6.4E-05
12	SiCL	CL	0.471	0.342	0.210	4.2E-05
13	SC	CH	0.430	0.321	0.221	3.3E-05
14	SiC	CH	0.479	0.371	0.251	2.5E-05
15	C	CH	0.475	0.378	0.265	1.7E-05
16	Liner Soil		0.430	0.366	0.280	1.0E-07
17	Liner Soil		0.400	0.356	0.290	1.0E-08
18	Mun. Waste		0.520	0.294	0.140	2.0E-04
19	USER SPECIFIED SOIL CHARACTERISTICS					
20	USER SPECIFIED SOIL CHARACTERISTICS					

From "Geotechnical Fabrics Report" Dec. 1989

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DRAINAGE PRODUCTS

Product Name	Structure[1]	Polymer Composition	Dimensional Properties: Width/Length m (ft)	Dimensional Properties: Thickness ASTM D1777[2] mm (mils)	Crush Strength ASTM D1621 kPa (psi)	Transmissivity: Geotextile Product if attached[3]	Transmissivity ASTM D4716-87[4]: 10 kPa (1.45 psi) M²/S (gal/min/ft)	Transmissivity ASTM D4716-87[4]: 100 kPa (14.5 psi) M²/S (gal/min/ft)
Contech Construction Products Inc.								
C-112	geonet with laminated geotextile	polyethylene	1.6/7.6,30.5 (5.2/25,100)	5.6 (220)	na	Trevira 1112	na	na
C-114	geonet with laminated geotextile	polyethylene	1.6/7.6,30.5 (5.2/25,100)	5.6 (220)	na	Trevira 1114	na	na
C-212	geonet with laminated geotextile	polyethylene	1.6/7.6,30.5 (5.2/25,100)	5.6 (220)	na	Trevira 1112	na	na
C-214	geonet with laminated geotextile	polyethylene	1.6/7.6,30.5 (5.2/25,100)	5.6 (220)	na	Trevira 1114	na	na
STRIPDRAIN 100	cuspated core & overwrapped geotextile	HDPE	.30,.46,.61,.76,.91/122 (1,1.5,2,2.5,3/400)	25.4 (1000)	379 (55)	Trevira 1114	5.11 (24.7)	4.66 (22.5)
STRIPDRAIN 75	cuspated core & laminated geotextile	HDPE	.55,1.1/55 (1.8,3.6/180)	19.1 (750)	276 (40)	Trevira 1114	.62 (3)	.41 (2)
Conwed Plastics								
LXE-9000	thermoformed net	polyethylene	1.2/30.5 (4/100)	15.2 (600)	280 (40)	various	7.4 (35.8)[A, D]	6.6 (31.9)[D]
XB8110	geonet	polyethylene	2.1/91.4 (6.9/300)	6.1 (240)	>900 (130)	various	3.4 (16.4)[A, D]	3.0 (14.5)[D]
XB8210	geonet	polyethylene	2.1/91.4 (6.9/300)	4.1 (160)	>900 (130)	various	1.9 (9.2)[A, D]	1.8 (8.7)[D]
XB8310	geonet	polyethylene	2.1/91.4 (6.9/300)	4.8 (190)	>900 (130)	various	2.7 (13.0)[A, D]	2.6 (12.6)[D]
XB8315CN	geonet	polyethylene	2.1/91.4 (6.9/300)	5.1 (200)	>900 (130)	various	2.6 (12.6)[A, D]	2.6 (12.6)[D]
XB8410	geonet	polyethylene	2.1/67.1 (6.9/220)	7.6 (360)	>900 (130)	various	4.3 (20.8)[A, D]	4.3 (20.8)[D]
Fluid Systems Inc.								
TEX-NET TN1001	geonet composite	polyethylene	(7.5/250)	5.7 (225)	>900 (130)	Trevira 1120[B]	.0015	.0015
TEX-NET TN3001	geonet composite	polyethylene	(7.5/300)	5.1 (200)	>900 (130)	Trevira 1120[B]	.0012	.0012
TEX-NET TN3001CN	geonet composite	polyethylene	(7.5/300)	5.1 (200)	<900 (130)	Trevira 1120[B]	.0010	.0010
TEX-NET TN4001	geonet composite	polyethylene	(7.5/250)	6.9 (270)	<900 (130)	Trevira 1120[B]	.0025	.0025
Greenstreak Inc.								
Deck Drain	composite single-side core	polystyrene	1.2/3.0 (4/10)	9.6 (380)	958 (139)	Amoco 1198 woven polypropylene	1.5-4.8 (7-23)[C]	1.2-4.6 (6-22)[C]
Sheet Drain	composite single-side core	polystyrene	1.2/3.0 (4/10)	9.6 (380)	717 (104)	Amoco 9140 NP polypropylene	1.2-3.9 (6-19)[C]	1-3.7 (5-18)[C]
Sheet Drain HS	composite single-side core	polystyrene	1.2/3.0 (4/10)	5.3 (210)	1199 (174)	Amoco 9140 NP polypropylene	.3-1.1 (1.3-5.2)[C]	.2-10 (1.1-4.9)[C]

[A] 48 kPa – 6.9 psi
[B] Available on both sides

[C] Gradient range of .1 – 1.0
[D] Gradient of .25

All values were requested to be minimum average roll values and all claims are the responsibility of the manufacturer. All product data are intended as a guide. *Geotechnical Fabrics Report* recommends you contact manufacturers before making any specifying/purchasing decisions.

903-6402
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7/28

CASE 1

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GOOD GRASS

LAYER 1

VERTICAL PERCOLATION LAYER

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4530 VOL/VOL
FIELD CAPACITY	=	0.1907 VOL/VOL
WILTING POINT	=	0.0849 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2183 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.003023999760 CM/SEC

LAYER 2

LATERAL DRAINAGE LAYER

THICKNESS	=	102.00 INCHES
POROSITY	=	0.4170 VOL/VOL
FIELD CAPACITY	=	0.0457 VOL/VOL
WILTING POINT	=	0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1606 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.001000000475 CM/SEC
SLOPE	=	5.00 PERCENT
DRAINAGE LENGTH	=	260.0 FEET

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LAYER 3

BARRIER SOIL LINER WITH FLEXIBLE MEMBRANE LINER

THICKNESS	=	0.06 INCHES
POROSITY	=	0.4000 VOL/VOL
FIELD CAPACITY	=	0.3563 VOL/VOL
WILTING POINT	=	0.2901 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4000 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.0000000100000 CM/SEC
LINER LEAKAGE FRACTION	=	0.00000000

GENERAL SIMULATION DATA

SCS RUNOFF CURVE NUMBER	=	60.10
TOTAL AREA OF COVER	=	43560. SQ FT
EVAPORATIVE ZONE DEPTH	=	24.00 INCHES
UPPER LIMIT VEG. STORAGE	=	10.4400 INCHES
INITIAL VEG. STORAGE	=	3.7728 INCHES

SOIL WATER CONTENT INITIALIZED BY PROGRAM.

CLIMATOLOGICAL DATA

SYNTHETIC RAINFALL WITH SYNTHETIC DAILY TEMPERATURES AND
SOLAR RADIATION FOR BOSTON MASS

MAXIMUM LEAF AREA INDEX	=	3.30
START OF GROWING SEASON (JULIAN DATE)	=	127
END OF GROWING SEASON (JULIAN DATE)	=	290

NORMAL MEAN MONTHLY TEMPERATURES, DEGREES FAHRENHEIT

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
29.60	30.70	38.40	48.70	58.50	68.00
73.50	71.90	64.60	54.80	45.20	33.30

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 20

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.44	3.64	4.56	3.49	3.45	3.53
	3.06	3.53	3.18	3.34	4.78	5.26
STD. DEVIATIONS	1.96	1.72	1.85	1.44	1.41	1.67
	1.44	1.38	1.94	1.39	2.06	2.02
RUNOFF						
TOTALS	0.000	0.000	0.001	0.008	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.002
STD. DEVIATIONS	0.000	0.000	0.004	0.036	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.006
EVAPOTRANSPIRATION						
TOTALS	0.894	1.265	2.231	2.627	2.625	4.616
	3.251	3.099	2.816	1.769	1.259	0.903
STD. DEVIATIONS	0.179	0.188	0.261	0.691	0.722	0.927
	1.262	1.279	0.935	0.525	0.222	0.143
LATERAL DRAINAGE FROM LAYER 2						
TOTALS	1.4415	1.4096	1.6601	1.6369	1.6095	1.4863
	1.4215	1.3165	1.1880	1.1636	1.1495	1.3490
STD. DEVIATIONS	0.3480	0.3505	0.4357	0.4865	0.4104	0.3625
	0.3181	0.2865	0.2540	0.2384	0.2057	0.2624
PERCOLATION FROM LAYER 3						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 20

	(INCHES)		(CU. FT.)	PERCENT
PRECIPITATION	45.27	(4.848)	164343.	100.00
RUNOFF	0.011	(0.036)	40.	0.02

EVAPOTRANSPIRATION	27.356	(2.699)	99303.	60.42
LATERAL DRAINAGE FROM LAYER 2	16.8319	(3.7774)	61100.	37.18
PERCOLATION FROM LAYER 3	0.0000	(0.0000)	0.	0.00
CHANGE IN WATER STORAGE	1.074	(3.495)	3900.	2.37

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 20

	(INCHES)	(CU. FT.)
PRECIPITATION	3.45	12523.5
RUNOFF	0.162	586.4
LATERAL DRAINAGE FROM LAYER 2	0.1153	418.6
PERCOLATION FROM LAYER 3	0.0000	0.0
HEAD ON LAYER 3	113.6	
SNOW WATER	3.10	11253.0

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4309
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0524

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FINAL WATER STORAGE AT END OF YEAR 20

LAYER	(INCHES)	(VOL/VOL)
1	2.53	0.2108
2	37.77	0.3703
3	0.02	0.4000

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SNOW WATER 0.00

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CASE 2

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GOOD GRASS

LAYER 1

VERTICAL PERCOLATION LAYER

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4530 VOL/VOL
FIELD CAPACITY	=	0.1907 VOL/VOL
WILTING POINT	=	0.0849 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2180 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.0030239999760 CM/SEC

LAYER 2

LATERAL DRAINAGE LAYER

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4170 VOL/VOL
FIELD CAPACITY	=	0.0457 VOL/VOL
WILTING POINT	=	0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0770 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.0500000007451 CM/SEC
SLOPE	=	5.00 PERCENT
DRAINAGE LENGTH	=	260.0 FEET

LAYER 3

BARRIER SOIL LINER WITH FLEXIBLE MEMBRANE LINER

THICKNESS	=	0.06 INCHES

13/23

POROSITY	=	0.4000 VOL/VOL
FIELD CAPACITY	=	0.3563 VOL/VOL
WILTING POINT	=	0.2901 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4000 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.0000000100000 CM/SEC
LINER LEAKAGE FRACTION	=	0.00000000

GENERAL SIMULATION DATA

SCS RUNOFF CURVE NUMBER	=	60.10
TOTAL AREA OF COVER	=	43560. SQ FT
EVAPORATIVE ZONE DEPTH	=	24.00 INCHES
UPPER LIMIT VEG. STORAGE	=	10.4400 INCHES
INITIAL VEG. STORAGE	=	3.3789 INCHES

SOIL WATER CONTENT INITIALIZED BY PROGRAM.

CLIMATOLOGICAL DATA

SYNTHETIC RAINFALL WITH SYNTHETIC DAILY TEMPERATURES AND SOLAR RADIATION FOR BOSTON MASS

MAXIMUM LEAF AREA INDEX	=	3.30
START OF GROWING SEASON (JULIAN DATE)	=	127
END OF GROWING SEASON (JULIAN DATE)	=	290

NORMAL MEAN MONTHLY TEMPERATURES, DEGREES FAHRENHEIT

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
29.60	30.70	38.40	48.70	58.50	68.00
73.50	71.90	64.60	54.80	45.20	33.30

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 20

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.44	3.64	4.56	3.49	3.45	3.53
	3.06	3.53	3.18	3.34	4.78	5.26
STD. DEVIATIONS	1.96	1.72	1.85	1.44	1.41	1.67
	1.44	1.38	1.94	1.39	2.06	2.02

RUNOFF

TOTALS	0.000	0.000	0.001	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.002
STD. DEVIATIONS	0.000	0.000	0.003	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.006

EVAPOTRANSPIRATION

TOTALS	0.901	1.271	2.235	2.626	2.618	4.169
	3.117	3.060	2.791	1.761	1.272	0.913
STD. DEVIATIONS	0.184	0.189	0.260	0.700	0.731	0.995
	1.198	1.210	0.956	0.542	0.233	0.144

LATERAL DRAINAGE FROM LAYER 2

TOTALS	3.2135	2.5116	2.8040	1.4960	0.7374	0.4943
	0.0826	0.0509	0.3017	0.6967	2.2933	3.7608
STD. DEVIATIONS	1.3316	1.5998	1.4928	1.3609	0.5200	0.7414
	0.1830	0.1131	0.5751	0.7404	1.6222	1.5855

PERCOLATION FROM LAYER 3

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 20

	(INCHES)		(CU. FT.)	PERCENT
PRECIPITATION	45.27	(4.848)	164343.	100.00
RUNOFF	0.003	(0.007)	11.	0.01
EVAPOTRANSPIRATION	26.735	(2.631)	97049.	59.05
LATERAL DRAINAGE FROM LAYER 2	18.4429	(4.7906)	66948.	40.74
PERCOLATION FROM LAYER 3	0.0000	(0.0000)	0.	0.00
CHANGE IN WATER STORAGE	0.092	(1.088)	335.	0.20

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 20

	(INCHES)	(CU. FT.)
PRECIPITATION	3.45	12523.5
RUNOFF	0.018	65.3
LATERAL DRAINAGE FROM LAYER 2	0.3165	1148.9
PERCOLATION FROM LAYER 3	0.0000	0.0
HEAD ON LAYER 3	18.6	
SNOW WATER	3.10	11253.0

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3790

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0523

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FINAL WATER STORAGE AT END OF YEAR 20

LAYER	(INCHES)	(VOL/VOL)
1	2.53	0.2108
2	2.68	0.2233
3	0.02	0.4000
SNOW WATER	0.00	

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16/23

CASE 3

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GOOD GRASS

LAYER 1

VERTICAL PERCOLATION LAYER

THICKNESS	=	18.00 INCHES
POROSITY	=	0.4530 VOL/VOL
FIELD CAPACITY	=	0.1907 VOL/VOL
WILTING POINT	=	0.0849 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2218 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.0030239999760 CM/SEC

LAYER 2

LATERAL DRAINAGE LAYER

THICKNESS	=	0.20 INCHES
POROSITY	=	0.8000 VOL/VOL
FIELD CAPACITY	=	0.0300 VOL/VOL
WILTING POINT	=	0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0391 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	19.6000003814697 CM/SEC
SLOPE	=	5.00 PERCENT
DRAINAGE LENGTH	=	260.0 FEET

LAYER 3

BARRIER SOIL LINER WITH FLEXIBLE MEMBRANE LINER

THICKNESS	=	0.06 INCHES

17/23

POROSITY	=	0.4000 VOL/VOL
FIELD CAPACITY	=	0.3563 VOL/VOL
WILTING POINT	=	0.2901 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4000 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.0000000100000 CM/SEC
LINER LEAKAGE FRACTION	=	0.00000000

GENERAL SIMULATION DATA

SCS RUNOFF CURVE NUMBER	=	60.10
TOTAL AREA OF COVER	=	43560. SQ FT
EVAPORATIVE ZONE DEPTH	=	18.00 INCHES
UPPER LIMIT VEG. STORAGE	=	8.1540 INCHES
INITIAL VEG. STORAGE	=	3.8242 INCHES

SOIL WATER CONTENT INITIALIZED BY PROGRAM.

CLIMATOLOGICAL DATA

SYNTHETIC RAINFALL WITH SYNTHETIC DAILY TEMPERATURES AND SOLAR RADIATION FOR BOSTON MASS

MAXIMUM LEAF AREA INDEX	=	3.30
START OF GROWING SEASON (JULIAN DATE)	=	127
END OF GROWING SEASON (JULIAN DATE)	=	290

NORMAL MEAN MONTHLY TEMPERATURES, DEGREES FAHRENHEIT

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
29.60	30.70	38.40	48.70	58.50	68.00
73.50	71.90	64.60	54.80	45.20	33.30

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 20

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.44	3.64	4.56	3.49	3.45	3.53
	3.06	3.53	3.18	3.34	4.78	5.26
STD. DEVIATIONS	1.96	1.72	1.85	1.44	1.41	1.67
	1.44	1.38	1.94	1.39	2.06	2.02

RUNOFF

TOTALS	0.000	0.000	0.002	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.002
STD. DEVIATIONS	0.000	0.000	0.007	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.006

EVAPOTRANSPIRATION

TOTALS	0.899	1.270	2.278	2.688	2.696	4.431
	3.183	3.093	2.841	1.805	1.271	0.911
STD. DEVIATIONS	0.181	0.190	0.255	0.705	0.741	0.961
	1.237	1.276	0.975	0.533	0.231	0.144

LATERAL DRAINAGE FROM LAYER 2

TOTALS	2.7672	2.5445	2.4116	1.2799	0.6128	0.4751
	0.0446	0.0138	0.2210	0.5794	2.6960	4.2391
STD. DEVIATIONS	1.7261	1.7211	1.5448	1.3091	0.4994	0.7530
	0.1294	0.0426	0.4785	0.7289	1.9596	2.2174

PERCOLATION FROM LAYER 3

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 20

	(INCHES)		(CU. FT.)	PERCENT
PRECIPITATION	45.27	(4.848)	164343.	100.00
RUNOFF	0.004	(0.011)	14.	0.01
EVAPOTRANSPIRATION	27.364	(2.698)	99331.	60.44
LATERAL DRAINAGE FROM LAYER 2	17.8849	(4.6650)	64922.	39.50
PERCOLATION FROM LAYER 3	0.0000	(0.0000)	0.	0.00
CHANGE IN WATER STORAGE	0.021	(0.790)	76.	0.05

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 20

	(INCHES)	(CU. FT.)
PRECIPITATION	3.45	12523.5
RUNOFF	0.030	109.9
LATERAL DRAINAGE FROM LAYER 2	1.7169	6232.4
PERCOLATION FROM LAYER 3	0.0000	0.0
HEAD ON LAYER 3	10.5	
SNOW WATER	3.10	11253.0

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3679

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0846

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FINAL WATER STORAGE AT END OF YEAR 20

LAYER	(INCHES)	(VOL/VOL)
1	4.22	0.2343
2	0.02	0.1063
3	0.02	0.4000
SNOW WATER	0.00	

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G03-6400
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20/2

CASE 4

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GOOD GRASS

LAYER 1

VERTICAL PERCOLATION LAYER

THICKNESS	=	18.00 INCHES
POROSITY	=	0.4530 VOL/VOL
FIELD CAPACITY	=	0.1907 VOL/VOL
WILTING POINT	=	0.0849 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2218 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.0030239999760 CM/SEC

LAYER 2

LATERAL DRAINAGE LAYER

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4170 VOL/VOL
FIELD CAPACITY	=	0.0457 VOL/VOL
WILTING POINT	=	0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0470 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.3300000131130 CM/SEC
SLOPE	=	5.00 PERCENT
DRAINAGE LENGTH	=	260.0 FEET

LAYER 3

BARRIER SOIL LINER WITH FLEXIBLE MEMBRANE LINER

THICKNESS	=	0.06 INCHES

POROSITY	=	0.4000 VOL/VOL
FIELD CAPACITY	=	0.3563 VOL/VOL
WILTING POINT	=	0.2901 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4000 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.0000000100000 CM/SEC
LINER LEAKAGE FRACTION	=	0.00000000

GENERAL SIMULATION DATA

SCS RUNOFF CURVE NUMBER	=	60.10
TOTAL AREA OF COVER	=	43560. SQ FT
EVAPORATIVE ZONE DEPTH	=	18.00 INCHES
UPPER LIMIT VEG. STORAGE	=	8.1540 INCHES
INITIAL VEG. STORAGE	=	3.8245 INCHES

SOIL WATER CONTENT INITIALIZED BY PROGRAM.

CLIMATOLOGICAL DATA

SYNTHETIC RAINFALL WITH SYNTHETIC DAILY TEMPERATURES AND SOLAR RADIATION FOR BOSTON MASS

MAXIMUM LEAF AREA INDEX	=	3.30
START OF GROWING SEASON (JULIAN DATE)	=	127
END OF GROWING SEASON (JULIAN DATE)	=	290

NORMAL MEAN MONTHLY TEMPERATURES, DEGREES FAHRENHEIT

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
29.60	30.70	38.40	48.70	58.50	68.00
73.50	71.90	64.60	54.80	45.20	33.30

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 20

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.44	3.64	4.56	3.49	3.45	3.53
	3.06	3.53	3.18	3.34	4.78	5.26
STD. DEVIATIONS	1.96	1.72	1.85	1.44	1.41	1.67
	1.44	1.38	1.94	1.39	2.06	2.02

RUNOFF

TOTALS	0.000	0.000	0.002	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.002
STD. DEVIATIONS	0.000	0.000	0.007	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.006

EVAPOTRANSPIRATION

TOTALS	0.899	1.270	2.277	2.687	2.696	4.431
	3.183	3.093	2.841	1.805	1.270	0.911
STD. DEVIATIONS	0.181	0.190	0.255	0.704	0.741	0.961
	1.237	1.276	0.975	0.533	0.231	0.144

LATERAL DRAINAGE FROM LAYER 2

TOTALS	2.7401	2.5595	2.4584	1.2806	0.6296	0.4858
	0.0415	0.0174	0.2146	0.5599	2.6263	4.2665
STD. DEVIATIONS	1.6298	1.7343	1.5592	1.3223	0.5127	0.7544
	0.1167	0.0575	0.4699	0.7332	1.9852	2.2919

PERCOLATION FROM LAYER 3

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

****

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 20

	(INCHES)		(CU. FT.)	PERCENT
PRECIPITATION	45.27	(4.848)	164343.	100.00
RUNOFF	0.004	(0.011)	14.	0.01
EVAPOTRANSPIRATION	27.363	(2.699)	99327.	60.44
LATERAL DRAINAGE FROM LAYER 2	17.8801	(4.6743)	64905.	39.49
PERCOLATION FROM LAYER 3	0.0000	(0.0000)	0.	0.00
CHANGE IN WATER STORAGE	0.027	(0.780)	97.	0.06

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 20

	(INCHES)	(CU. FT.)
PRECIPITATION	3.45	12523.5
RUNOFF	0.030	109.9
LATERAL DRAINAGE FROM LAYER 2	0.9907	3596.3
PERCOLATION FROM LAYER 3	0.0000	0.0
HEAD ON LAYER 3	5.0	
SNOW WATER	3.10	11253.0

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3432
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0846

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FINAL WATER STORAGE AT END OF YEAR 20

LAYER	(INCHES)	(VOL/VOL)
1	4.22	0.2343
2	0.69	0.0579
3	0.02	0.4000
SNOW WATER	0.00	

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APPENDIX 12-G

Drainage Channel and Culvert Calculations

Golder Associates	SUBJECT East Hide Pile - Drainage Channel		
	Job No. 913-6120.220 Ref.	Made by DJC Checked A.K Reviewed KCR	Date 7/16/91 Sheet 1 of 25

OBJECTIVE: TO DESIGN A DRAINAGE CHANNEL FOR SURFACE WATER ON THE EAST HIDE PILE.

METHOD:

1) USE QUICK TR55 TO DETERMINE THE MAXIMUM FLOW IN THE CHANNEL BASED ON A 24 hr - 100 yr STORM.

2) USE THE MAXIMUM FLOW TO DETERMINE THE SIZE AND SHAPE OF THE CHANNEL, MAXIMUM DEPTH OF FLOW AND LINING MATERIAL

3) FOLLOW THE GUIDELINES SET FORTH IN THE "NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORT NO 108" TO DETERMINE MANNING'S 'n' AND MAXIMUM STONE SIZE

4) MAXIMUM VELOCITIES FOR A GIVEN MAXIMUM RIPRAP SIZE SHALL BE BASED ON CURVE 16-1, page 16-20 OF THE ENGINEERING FIELD MANUAL.

5) RIPRAP THICKNESS SHALL BE THE MAXIMUM STONE SIZE PLUS A LAYER OF 16 OUNCE NONWOVEN GEOTEXTILE AS REFERENCED IN REPORT NO 468 OF THE NATIONAL HANDBOOK OF CONSERVATION PRACTICES.

6) DETERMINE CULVERT SIZES BASED ON CONCRETE PIPE DESIGN MANUAL.

REFERENCES:

1. NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM REPORT 108, TENTATIVE DESIGN PROCEDURE FOR RIPRAP LINED CHANNELS, ALVIN G ANDERSON, AMREEK S PAINTAL AND JOHN T DAVENPORT, 1970.

2. REPORT 468, NATIONAL HANDBOOK OF CONSERVATION PRACTICES

3. SOIL CONSERVATION SERVICES ENGINEERING FIELD MANUAL.

CALCULATIONS:

CALCULATIONS FOLLOW

Golder Associates	SUBJECT East Hide Pile Drainage Channel		
	Job No. 903-6400.220 Ref.	Made by GAL Checked [illegible] Reviewed [illegible]	Date 7/[illegible] Sheet 2 of 25

ASSUMPTIONS:

- CN VALUES

CN = 95 FOR PROPOSED COVER
CN = 79 FOR EXISTING CONDITIONS

REACH 1A - 1E - CHANNEL SECTION FROM CREST TO SOUTHERN EDGE OF EAST HIDE PILE

REACH 2A - 2C - CHANNEL SECTION ALONG NORTHEAST EDGE OF PILE

REACH 2D - 2F - CHANNEL SECTION ALONG NORTHERN EDGE OF PILE

Golder Associates		
SUBJECT DRAINAGE CHANNEL CALCULATIONS		
Job No. 9134100.220	Made by [illegible]	Date 5/14/91
Ref. EAST HIDE PILE	Checked	Sheet 3 of 25
	Reviewed [illegible]	

OBJECTIVE: TO DETERMINE THE AREAS OF DRAINAGE TO A CHANNEL ALONG THE EAST HIDE PILE

PROCEDURE: USE A PLANIMETER TO FIND THE AREAS OF I THROUGH VI (See Figure in page 13/25)

AREA	$Area_1$ (ft^2)	$Area_2$ (ft^2)	Avg Area (ft^2)	Avg Area (acre)
I	30341	30186	30,264	0.69
II	48283	48321	48,302	1.1
III	8436	8343	8,390	0.19
IV	43129	43323	43,226	0.99
V	55994	56033	56,014	1.29
VI	7944	7905	7,925	0.18

NOTE: 8/7/91) ALIGNMENT OF DRAINAGE CHANNEL AND CULVERT ALONG NORTHEAST EDGE OF EAST HIDE PILE HAS BEEN MODIFIED, THE NEW ALIGNMENT AS SHOWN ON SHEET 12-1 SLIGHTLY DECREASES DRAINAGE AREAS III AND V THUS THIS ANALYSIS IS CONSERVATIVE.

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

4/25

Project ISRT ______ By RAC Date 5/17/91

Location ______ Checked ______ Date ______

Circle one: Present Developed

Circle one: T_c T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

AREA I

Sheet flow (Applicable to T_c only)		Segment ID	1		
1. Surface description (table 3-1)			SMOOTH SURFACE BARE SOIL		
2. Manning's roughness coeff., n (table 3-1) ..			0.011	0.011	
3. Flow length, L (total L ≤ 300 ft)	ft		147	125	
4. Two-yr 24-hr rainfall, P_2	in		3.3	3.3	
5. Land slope, s	ft/ft		0.075	0.28	
6. $T_t = \frac{0.007 (nL)^{0.8}}{P_2^{0.5} s^{0.4}}$ Compute T_t	hr		0.016 +	0.007	= 0.024

Shallow concentrated flow		Segment ID			
7. Surface description (paved or unpaved)					
8. Flow length, L	ft				
9. Watercourse slope, s	ft/ft				
10. Average velocity, V (figure 3-1)	ft/s				
11. $T_t = \frac{L}{3600 V}$ Compute T_t	hr		+		=

Channel flow		Segment ID			
12. Cross sectional flow area, a	ft^2				
13. Wetted perimeter, p_w	ft				
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft				
15. Channel slope, s	ft/ft				
16. Manning's roughness coeff., n					
17. $V = \frac{1.49 r^{2/3} s^{1/2}}{n}$ Compute V	ft/s				
18. Flow length, L	ft				
19. $T_t = \frac{L}{3600 V}$ Compute T_t	hr		+		=

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr 0.024

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

5/25

Project ISBT / East Side [illegible] By [illegible] Date 5/17/91

Location [illegible] Checked [illegible] Date [illegible]

Circle one: Present Developed

Circle one: T_c T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

AREA I

Sheet flow (Applicable to T_c only)	Units			
Segment ID		2a	2b	
1. Surface description (table 3-1)		Dense [illegible]	[illegible]	
2. Manning's roughness coeff., n (table 3-1) ..		0.8	0.15	
3. Flow length, L (total L ≤ 300 ft)	ft	95	205	
4. Two-yr 24-hr rainfall, P_2	in	3.3	3.3	
5. Land slope, s	ft/ft	0.057	0.049	
6. $T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$ Compute T_t	hr	0.387	+ 0.199	= 0.586

Shallow concentrated flow	Units			
Segment ID		2c	2d (Creek)	
7. Surface description (paved or unpaved)		Unpaved	Unpaved	
8. Flow length, L	ft	30	145	
9. Watercourse slope, s	ft/ft	0.15	0.155	
10. Average velocity, V (figure 3-1)	ft/s	6.25	6.3	
11. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr	0.0013	+ 0.0064	= 0.0077

Channel flow	Units			
Segment ID				
12. Cross sectional flow area, a	ft^2			
13. Wetted perimeter, p_w	ft			
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft			
15. Channel slope, s	ft/ft			
16. Manning's roughness coeff., n				
17. $V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s			
18. Flow length, L	ft			
19. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+	=
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19)	hr			

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

6/25

Project 15RT /EAT [illegible] By [illegible] Date 5/-1/91

Location [illegible] Checked [illegible] Date [illegible]

Circle one: Present Developed

Circle one: T_c T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

AREA II

Sheet flow (Applicable to T_c only)	Unit	Segment 1	Segment 2	Total
Segment ID				
1. Surface description (table 3-1)				
2. Manning's roughness coeff., n (table 3-1) ..				
3. Flow length, L (total L $\leq$ 300 ft)	ft			
4. Two-yr 24-hr rainfall, P_2	in			
5. Land slope, s	ft/ft			
6. $T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$ Compute T_t	hr		+	=

Shallow concentrated flow	Unit	Segment 1	Segment 2	Total
Segment ID		2e		
7. Surface description (paved or unpaved)		Unpaved		
8. Flow length, L	ft	125		
9. Watercourse slope, s	ft/ft	0.104		
10. Average velocity, V (figure 3-1)	ft/s	5.25		
11. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr	0.0066	+	= 0.0066

Channel flow	Unit	Segment 1	Segment 2	Total
Segment ID				
12. Cross sectional flow area, a	ft^2			
13. Wetted perimeter, p_w	ft			
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft			
15. Channel slope, s	ft/ft			
16. Manning's roughness coeff., n				
17. $V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s			
18. Flow length, L	ft			
19. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+	=

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr 0.6

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

7/25

Project ISRT / EAST [illegible] By [illegible] Date 5/[illegible]/91

Location W[illegible], MA Checked ______ Date ______

Circle one: Present Developed ______________________

Circle one: T_c T_t through subarea ______________________

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

AREA II

Sheet flow (Applicable to T_c only)	Unit				
Segment ID		3			
1. Surface description (table 3-1)		SMOOTH SURFACE BARE	[illegible]		
2. Manning's roughness coeff., n (table 3-1) ..		0.011			
3. Flow length, L (total L ≤ 300 ft)	ft	135			
4. Two-yr 24-hr rainfall, P_2	in	3.3			
5. Land slope, s	ft/ft	0.14			
6. $T_t = \frac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$ Compute T_t	hr	0.012	+	=	0.012

Shallow concentrated flow	Unit				
Segment ID					
7. Surface description (paved or unpaved)					
8. Flow length, L	ft				
9. Watercourse slope, s	ft/ft				
10. Average velocity, V (figure 3-1)	ft/s				
11. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr		+	=	

Channel flow	Unit				
Segment ID					
12. Cross sectional flow area, a	ft^2				
13. Wetted perimeter, p_w	ft				
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft				
15. Channel slope, s	ft/ft				
16. Manning's roughness coeff., n					
17. $V = \frac{1.49\,r^{2/3}\,s^{1/2}}{n}$ Compute V	ft/s				
18. Flow length, L	ft				
19. $T_t = \frac{L}{3600\,V}$ Compute T_t	hr		+	=	

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr 0.012

8/25

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project ISET [illegible] By [illegible] Date 5/[illegible]/91

Location [illegible] Checked [illegible] Date [illegible]

Circle one: Present Developed

Circle one: T_c T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Area II

Sheet flow (Applicable to T_c only)	Unit	Segment	Segment	Total
Segment ID		4		
1. Surface description (table 3-1)		Short Grass		
2. Manning's roughness coeff., n (table 3-1) ..		0.15		
3. Flow length, L (total L ≤ 300 ft)	ft	250		
4. Two-yr 24-hr rainfall, P_2	in	3.3		
5. Land slope, s	ft/ft	0.16		
6. $T_t = \frac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$ Compute T_t	hr	0.146	+	= 0.146

Shallow concentrated flow	Unit	Segment	Segment	Total
Segment ID				
7. Surface description (paved or unpaved)				
8. Flow length, L	ft			
9. Watercourse slope, s	ft/ft			
10. Average velocity, V (figure 3-1)	ft/s			
11. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+	=

Channel flow	Unit	Segment	Segment	Total
Segment ID				
12. Cross sectional flow area, a	ft^2			
13. Wetted perimeter, p_w	ft			
14. Hydraulic radius, $r = \frac{a}{p_w}$ Compute r	ft			
15. Channel slope, s	ft/ft			
16. Manning's roughness coeff., n				
17. $V = \frac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s			
18. Flow length, L	ft			
19. $T_t = \frac{L}{3600\ V}$ Compute T_t	hr		+	=

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr 0.146

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

9/25

Project 15RT / EAST HIDE P... By RJC Date 5/14/91

Location ... MA Checked ... Date ...

Circle one: Present Developed

Circle one: T_c T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

AREA I

Sheet flow (Applicable to T_c only)

		Units				
	Segment ID		5			
1.	Surface description (table 3-1)		SMOOTH SURFACE BARE SOIL			
2.	Manning's roughness coeff., n (table 3-1) ..		0.011			
3.	Flow length, L (total L $\leq$ 300 ft)	ft	243			
4.	Two-yr 24-hr rainfall, P_2	in	5.3			
5.	Land slope, s	ft/ft	0.185			
6.	$T_t = \dfrac{0.007\,(nL)^{0.8}}{P_2^{0.5}\,s^{0.4}}$ Compute T_t	hr	0.016	+		= 0.016

Shallow concentrated flow

		Units				
	Segment ID					
7.	Surface description (paved or unpaved)					
8.	Flow length, L	ft				
9.	Watercourse slope, s	ft/ft				
10.	Average velocity, V (figure 3-1)	ft/s				
11.	$T_t = \dfrac{L}{3600\ V}$ Compute T_t	hr		+		=

Channel flow

		Units				
	Segment ID					
12.	Cross sectional flow area, a	ft^2				
13.	Wetted perimeter, p_w	ft				
14.	Hydraulic radius, $r = \dfrac{a}{p_w}$ Compute r	ft				
15.	Channel slope, s	ft/ft				
16.	Manning's roughness coeff., n					
17.	$V = \dfrac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s				
18.	Flow length, L	ft				
19.	$T_t = \dfrac{L}{3600\ V}$ Compute T_t	hr		+		=

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr 0.016

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

10/23

Project ESRT [illegible] By [illegible] Date 5/14/91

Location [illegible] Checked [illegible] Date 5/14/91

Circle one: Present Developed

Circle one: T_c T_t through subarea

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

Area II

Sheet flow (Applicable to T_c only)		Segment ID		
1. Surface description (table 3-1)		SMOOTH SURFACE [illegible]		
2. Manning's roughness coeff., n (table 3-1) ..		0.011		
3. Flow length, L (total L $\leq$ 300 ft)	ft	275		
4. Two-yr 24-hr rainfall, P_2	in	3.3		
5. Land slope, s	ft/ft	0.041		
6. $T_t = \dfrac{0.007\ (nL)^{0.8}}{P_2^{0.5}\ s^{0.4}}$ Compute T_t	hr	0.028	+	= 0.028

Shallow concentrated flow		Segment ID		
7. Surface description (paved or unpaved)				
8. Flow length, L	ft			
9. Watercourse slope, s	ft/ft			
10. Average velocity, V (figure 3-1)	ft/s			
11. $T_t = \dfrac{L}{3600\ V}$ Compute T_t	hr		+	=

Channel flow		Segment ID		
12. Cross sectional flow area, a	ft^2			
13. Wetted perimeter, p_w	ft			
14. Hydraulic radius, $r = \dfrac{a}{p_w}$ Compute r	ft			
15. Channel slope, s	ft/ft			
16. Manning's roughness coeff., n				
17. $V = \dfrac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V	ft/s			
18. Flow length, L	ft			
19. $T_t = \dfrac{L}{3600\ V}$ Compute T_t	hr		+	=

20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr 0.028

11/25

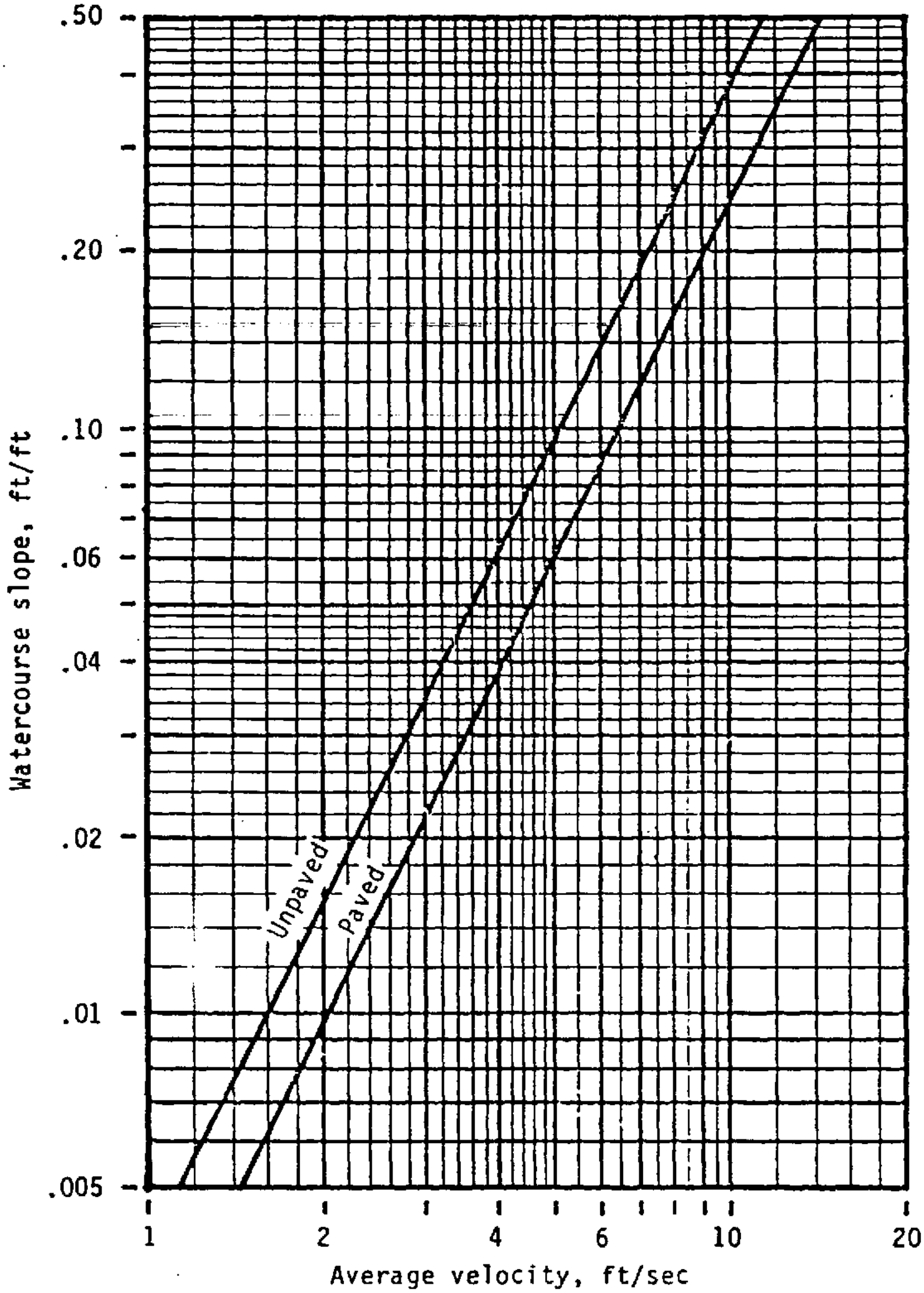


Figure 3-1.—Average velocities for estimating travel time for shallow concentrated flow.

12/25

Sheet flow

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment. These n values are for very shallow flow depths of about 0.1 foot or so. Table 3-1 gives Manning's n values for sheet flow for various surface conditions.

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overton and Meadows 1976) to compute T_t:

$$T_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,s^{0.4}} \qquad \text{[Eq. 3-3]}$$

Table 3-1.—Roughness coefficients (Manning's n) for sheet flow

Surface description	n[1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤20%	0.06
Residue cover >20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses[2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods:[3]	
Light underbrush	0.40
Dense underbrush	0.80

[1]The n values are a composite of information compiled by Engman (1986).
[2]Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
[3]When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

where

T_t = travel time (hr),
n = Manning's roughness coefficient (table 3-1),
L = flow length (ft),
P_2 = 2-year, 24-hour rainfall (in), and
s = slope of hydraulic grade line (land slope, ft/ft).

This simplified form of the Manning's kinematic solution is based on the following: (1) shallow steady uniform flow, (2) constant intensity of rainfall excess (that part of a rain available for runoff), (3) rainfall duration of 24 hours, and (4) minor effect of infiltration on travel time. Rainfall depth can be obtained from appendix B.

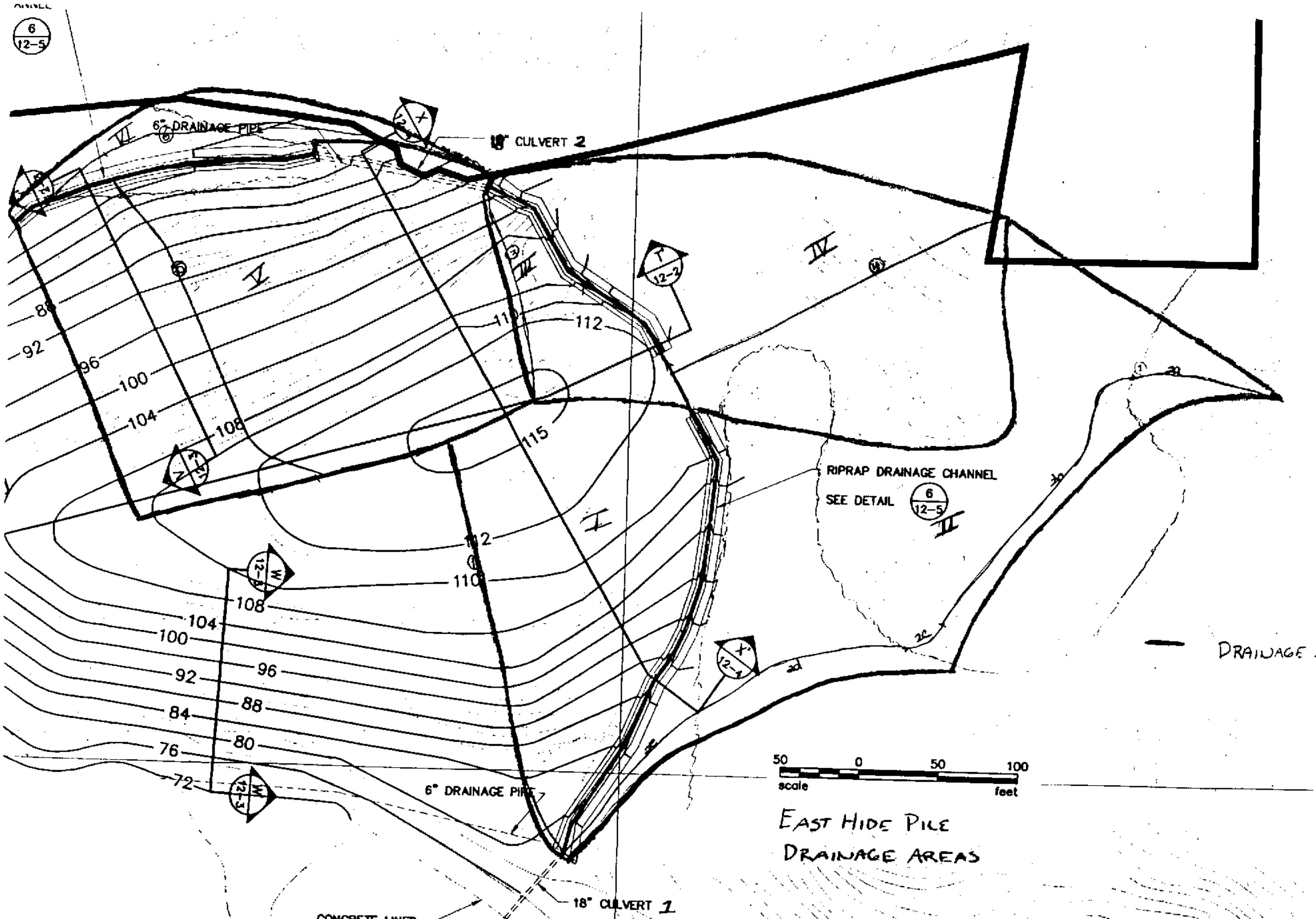
Shallow concentrated flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from figure 3-1, in which average velocity is a function of watercourse slope and type of channel. For slopes less than 0.005 ft/ft, use equations given in appendix F for figure 3-1. Tillage can affect the direction of shallow concentrated flow. Flow may not always be directly down the watershed slope if tillage runs across the slope.

After determining average velocity in figure 3-1, use equation 3-1 to estimate travel time for the shallow concentrated flow segment.

Open channels

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle sheets. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bank-full elevation.


6" DRAINAGE PIPE
18" CULVERT 2
RIPRAP DRAINAGE CHANNEL
SEE DETAIL 6/12-5
6" DRAINAGE PIPE
18" CULVERT 1
CONCRETE LINED
DRAINAGE AREA
50 0 50 100
scale feet
EAST HIDE PILE
DRAINAGE AREAS
I
II
III
IV
V
VI

TR-55 TABULAR DISCHARGE METHOD VERSION 1.11

Project : ISRT User: RAC Date: 07-16-91
County : Middlesex State: MA Checked: ____ Date: ________
Subtitle: East Hide Pile

Total watershed area: 0.001 sq mi Rainfall type: III Frequency: 100 years

	Subareas I
Area(sq mi)	0.00
Rainfall(in)	6.6
Curve number	95
Runoff(in)	6.01
Tc (hrs)	0.10
TimeToOutlet	0.00
Ia/P	0.02
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) I
11.0	0	0
11.3	0	0
11.6	0	0
11.9	1	1
12.0	2	2
12.1	3	3
12.2	4P	4P
12.3	4	4
12.4	2	2
12.5	2	2
12.6	1	1
12.7	1	1
12.8	1	1
13.0	1	1
13.2	0	0
13.4	0	0
13.6	0	0
13.8	0	0
14.0	0	0
14.3	0	0
14.6	0	0
15.0	0	0
15.5	0	0
16.0	0	0
16.5	0	0
17.0	0	0
17.5	0	0
18.0	0	0
19.0	0	0
20.0	0	0
22.0	0	0
26.0	0	0

P - Peak Flow

15/25

TR-55 TABULAR DISCHARGE METHOD VERSION 1.11

Project : ISRT User: RAC Date: 07-16-91
County : Middlesex State: MA Checked: ____ Date: ________
Subtitle: East Hide Pile

Total watershed area: 0.002 sq mi Rainfall type: III Frequency: 100 years

	Subareas
	II
Area(sq mi)	0.00
Rainfall(in)	6.6
Curve number	79
Runoff(in)	4.22
Tc (hrs)	0.60
(Used)	0.50
TimeToOutlet	0.00
Ia/P	0.08
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) II
11.0	0	0
11.3	0	0
11.6	0	0
11.9	0	0
12.0	1	1
12.1	1	1
12.2	1	1
12.3	2	2
12.4	2	2
12.5	3P	3P
12.6	3	3
12.7	3	3
12.8	2	2
13.0	2	2
13.2	1	1
13.4	1	1
13.6	1	1
13.8	0	0
14.0	0	0
14.3	0	0
14.6	0	0
15.0	0	0
15.5	0	0
16.0	0	0
16.5	0	0
17.0	0	0
17.5	0	0
18.0	0	0
19.0	0	0
[illegible]	0	0
[illegible]	0	0
26.0	0	0

P - Peak Flow

16/25

TR-55 TABULAR DISCHARGE METHOD VERSION 1.11

Project : ISRT User: RAC Date: 07-16-91
County : Middlesex State: MA Checked: ____ Date: ________
Subtitle: East Hide Pile

Total watershed area: 0.000 sq mi Rainfall type: III Frequency: 100 years

	Subareas
	III
Area(sq mi)	0.00
Rainfall(in)	6.6
Curve number	95
Runoff(in)	6.01
Tc (hrs)	0.10
TimeToOutlet	0.00
Ia/P	0.02
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) III
11.0	0	0
11.3	0	0
11.6	0	0
11.9	0	0
12.0	0	0
12.1	1P	1P
12.2	1	1
12.3	1	1
12.4	1	1
12.5	0	0
12.6	0	0
12.7	0	0
12.8	0	0
13.0	0	0
13.2	0	0
13.4	0	0
13.6	0	0
13.8	0	0
14.0	0	0
14.3	0	0
14.6	0	0
15.0	0	0
15.5	0	0
16.0	0	0
16.5	0	0
17.0	0	0
17.5	0	0
18.0	0	0
19.0	0	0
20.0	0	0
22.0	0	0
26.0	0	0

P - Peak Flow

17/25

TR-55 TABULAR DISCHARGE METHOD VERSION 1.11

Project : ISRT User: RAC Date: 07-16-91
County : Middlesex State: MA Checked: ____ Date: ________
Subtitle: East Hide Pile

Total watershed area: 0.002 sq mi Rainfall type: III Frequency: 100 years

	Subareas
	IV
Area(sq mi)	0.00
Rainfall(in)	6.6
Curve number	79
Runoff(in)	4.22
Tc (hrs)	0.15
(Used)	0.10
TimeToOutlet	0.00
Ia/P	0.08
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) IV
11.0	0	0
11.3	0	0
11.6	0	0
11.9	1	1
12.0	2	2
12.1	3	3
2	4P	4P
.3	3	3
12.4	2	2
12.5	2	2
12.6	1	1
12.7	1	1
12.8	1	1
13.0	1	1
13.2	0	0
13.4	0	0
13.6	0	0
13.8	0	0
14.0	0	0
14.3	0	0
14.6	0	0
15.0	0	0
15.5	0	0
16.0	0	0
16.5	0	0
17.0	0	0
17.5	0	0
18.0	0	0
0	0	0
0	0	0
22.0	0	0
26.0	0	0

P - Peak Flow

TR-55 TABULAR DISCHARGE METHOD

VERSION 1.11

Project : ISRT
County : Middlesex
Subtitle: East Hide Pile

State: MA

User: RAC
Checked: ____

Date: 07-16-91
Date: ________

Total watershed area: 0.002 sq mi Rainfall type: III Frequency: 100 years

	Subareas
	V
Area(sq mi)	0.00
Rainfall(in)	6.6
Curve number	95
Runoff(in)	6.01
Tc (hrs)	0.10
TimeToOutlet	0.00
Ia/P	0.02
(Used)	0.10

Time (hr)	Total Flow	Subarea Contribution to Total Flow (cfs) V
11.0	0	0
11.3	1	1
11.6	1	1
11.9	3	3
12.0	4	4
12.1	6	6
12.2	10P	10P
12.3	8	8
12.4	5	5
12.5	4	4
12.6	3	3
12.7	2	2
12.8	2	2
13.0	1	1
13.2	1	1
13.4	1	1
13.6	1	1
13.8	1	1
14.0	1	1
14.3	1	1
14.6	1	1
15.0	1	1
15.5	0	0
16.0	0	0
16.5	0	0
17.0	0	0
17.5	0	0
18.0	0	0
19.0	0	0
20.0	0	0
22.0	0	0
26.0	0	0

P - Peak Flow

TR-55 TABULAR DISCHARGE METHOD VERSION 1.11

Project : ISRT User: RAC Date: 07-16-91
County : Middlesex State: MA Checked: _____ Date: ________
Subtitle: East Hide Pile

Total watershed area: 0.000 sq mi Rainfall type: III Frequency: 100 years

	Subareas VI
Area(sq mi)	0.00
Rainfall(in)	6.6
Curve number	95
Runoff(in)	6.01
Tc (hrs)	0.10
TimeToOutlet	0.00
Ia/P	0.02
(Used)	0.10

Subarea Contribution to Total Flow (cfs)

Time (hr)	Total Flow	VI
11.0	0	0
11.3	0	0
11.6	0	0
11.9	0	0
12.0	0	0
12.1	1P	1P
12.2	1	1
12.3	1	1
12.4	1	1
12.5	0	0
12.6	0	0
12.7	0	0
12.8	0	0
13.0	0	0
13.2	0	0
13.4	0	0
13.6	0	0
13.8	0	0
14.0	0	0
14.3	0	0
14.6	0	0
15.0	0	0
15.5	0	0
16.0	0	0
16.5	0	0
17.0	0	0
17.5	0	0
18.0	0	0
19.0	0	0
20.0	0	0
22.0	0	0
26.0	0	0

P - Peak Flow

East Hide Pile Drainage Channel
903-6400.220
Date created: May 17,1991
Date revised: August 6,1991

Mannings equation

CHANNEL	side slope 1	side slope 2	base width (ft)	channel slope (ft/ft)	riprap D50 (ft)	Manning's n	design depth (ft)	required discharge (cfs)	Qmax (cfs)	velocity (ft/s)
1A	2	2	2	0.018	0.5	0.035	0.70	7	8.0	3.4
1B	2	2	2	0.087	0.5	0.035	0.50	7	9.4	6.2
1C	2	2	2	0.153	0.5	0.035	0.40	7	8.2	7.3
1D	2	2	2	0.069	0.5	0.035	0.50	7	8.3	5.6
1E	2	2	2	0.088	0.5	0.035	0.50	7	9.4	6.3
2A	2	2	2	0.014	0.5	0.035	0.60	5	5.3	2.8
2B	2	2	2	0.085	0.5	0.035	0.40	5	6.1	5.5
2C	2	2	4	0.094	0.5	0.035	0.50	16	17.6	7.0
2D	2	2	4	0.026	0.5	0.035	0.70	16	16.9	4.5
2E	2	2	4	0.014	0.5	0.035	0.85	16	17.6	3.6
trans	2	2	14	0.014	0.5	0.035	0.42	16	16.7	2.7

20/25

21/25

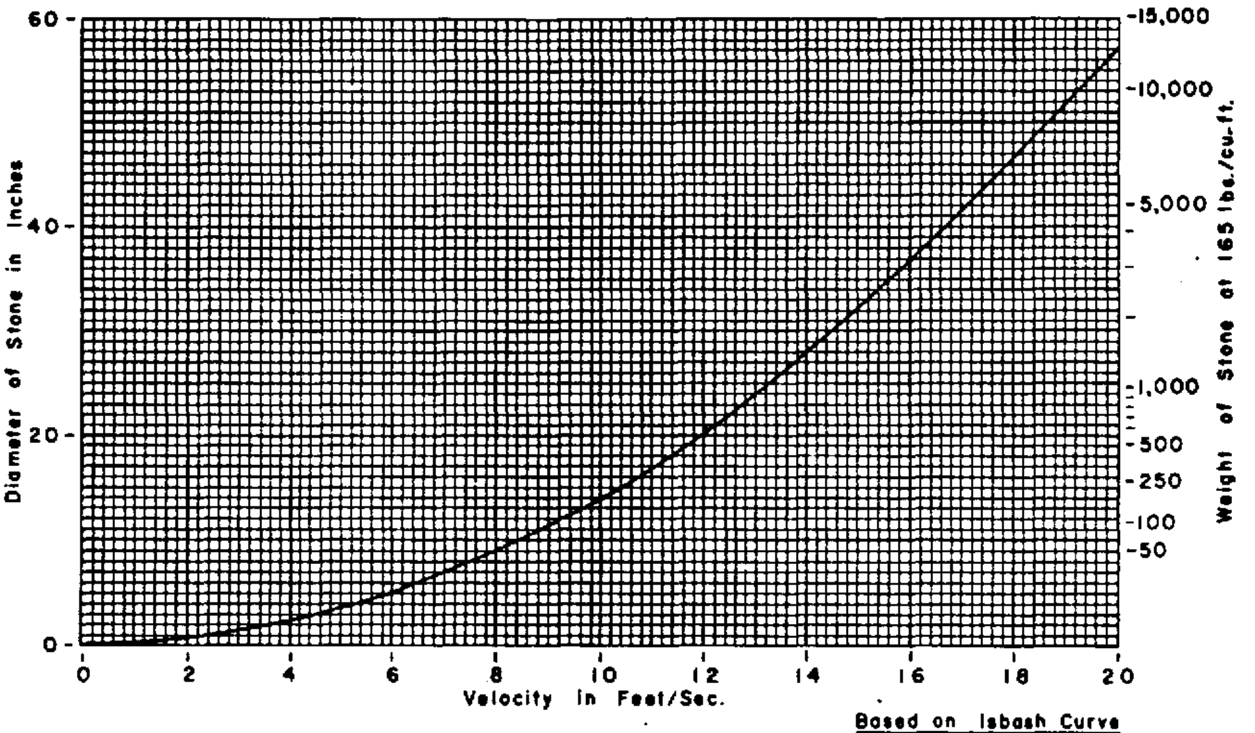


Exhibit 16-1 Maximum stone size for riprap

Golder Associates	SUBJECT Culvert Calculations - EHP		
	Job No. 983-6101.220	Made by HAC	Date 7/25/94
	Ref.	Checked	Sheet 22 of 25
		Reviewed PCR	

OBJECTIVE: TO DETERMINE THE SIZE OF THE CONCRETE CULVERTS BASED UPON THE MAXIMUM EXPECTED FLOW.

METHOD: USE THE PROCEDURE OUTLINED IN CONCRETE DESIGN MANUAL FOR THE SELECTION OF CULVERT SIZE.

REFERENCE: CONCRETE DESIGN MANUAL, prepared by AMERICAN CONCRETE PIPE ASSOCIATION, FEBRUARY 1985

ASSUMPTIONS:

1) CULVERT 1 IS LOCATED AT THE SOUTHEAST EDGE OF THE EAST HIDE PILE

2) CULVERT 2 IS LOCATED AT THE NORTHEAST EDGE OF THE EAST HIDE PILE

3) EXPECTED MAXIMUM FLOW IS BASED ON THE 24 hour, 100 YEAR STORM RAINFALL = 6.6 IN

Golder Associates	SUBJECT Culvert Calculations - EHP		
	Job No. 903-6100.220 Ref.	Made by RAC Checked ALK Reviewed RR	Date 9/25/91 Sheet 23 of 25

CALCULATIONS:

CULVERT 1

USE CULVERT CAPACITY CHARTS

Q = 7 cfs
L = 53 feet
S_o = 6.6 %
HW = 1.5 ft

ASSUME CONCRETE CULVERT, 18 INCH DIAMETER

FROM Fig. 44

INLET CONTROL HW = 1.45 ft

OUTLET CONTROL $HW + S_o L$ = 1.7 ft

HW = 1.7 ft − 0.066 (53 ft)
= −1.8

INLET HEADWATER IS GREATER THAN OUTLET HEADWATER, THEREFORE INLET CONTROL GOVERNS
AN 18 INCH DIAMETER WILL BE ADEQUATE

CULVERT 2

USE CULVERT CAPACITY CHARTS

Q = 5 cfs
L = 154 ft
S_o = 17 %
HW = 1.5 ft

ASSUME CONCRETE CULVERT, 18 INCH DIAMETER

FROM Fig 44

INLET CONTROL HW = 1.2 ft

OUTLET CONTROL $HW + S_o L$ = 1.7 ft

CALCULATIONS (cont'd)

OUTLET CONTROL

$$HW = 1.7 \text{ ft} - 154\text{ft}(0.17)$$
$$= -24.5 \text{ ft}$$

INLET HEADWATER IS GREATER THAN OUTLET HEADWATER, THEREFORE INLET CONTROL GOVERNS. AN 18 INCH DIAMETER WILL BE ADEQUATE

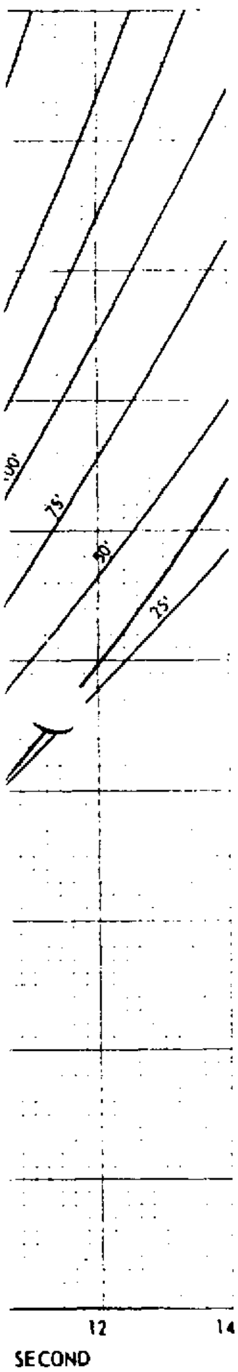
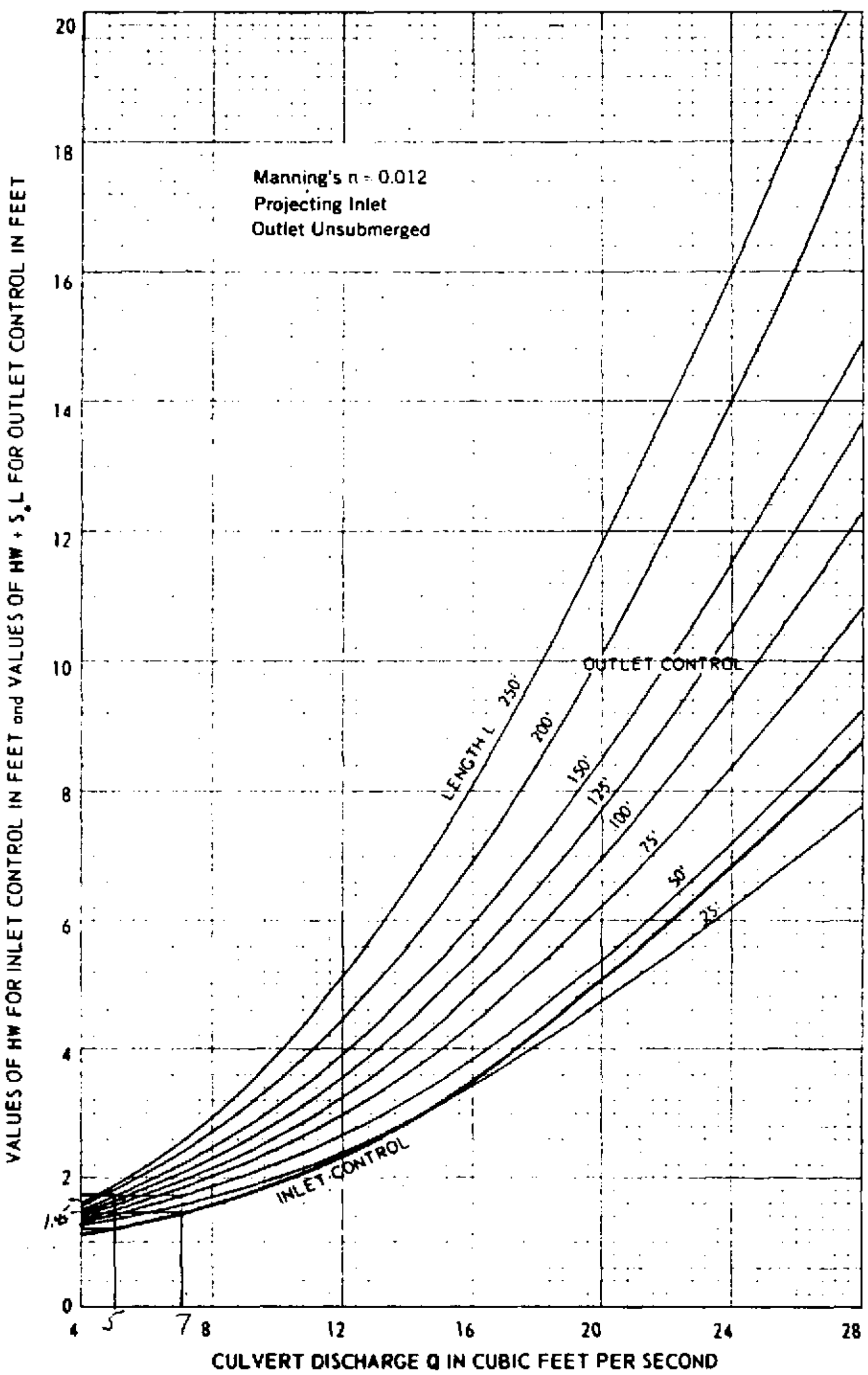


FIGURE 44

CULVERT CAPACITY
18-INCH DIAMETER PIPE



APPENDIX 12-H
Access Road Calculations

Golder Associates	SUBJECT East Hide Pile Gravel Access Road		
	Job No. 903-6400 Ref. INDUSTRI-PLEX WOBURN/MA	Made by DOKL Checked PCN Reviewed PCC PSR	Date 5/19/92 Sheet 1 of 4

Objective: To determine the material cross-section of a gravel access road to gas treatment plant at the East Hide Pile.

Method:

1) Determine the wheel load
2) Estimate the CBR of the subgrade and subbase material
3) Estimate the thickness of the gravel layer and subbase layer from Figure 1 based on the values of CBR of the subbase and subgrade layers.

References:

1) Bureau of Mines Information Circular IC 8758, 1977.
2) Golder 1990 "Pre-Design Investigation Task S-4, Foundation Data," Interim Final Report, Industri-Plex Site, Woburn MA Sept.

Golder Associates	SUBJECT East Hide Pile Gravel Access Road		
	Job No. 903-6400 Ref. INDUSTRI-PLEX /WOBURN/MA	Made by DOKL Checked DCN Reviewed PCC [initials]	Date 5/19/92 Sheet 2 of 4

Assumptions: 1) The maximum weight of the truck and its cargo is 8 tons.

2) Underlying soil: coarse to fine sand with some gravel, silt, pebbles and cobbles (taken from Ref. 2) From Fig 1, CBR of the subgrade is estimated to be about 15. ✓

3) Subbase fill is a mixture of sand gravel and fines. From Fig 1. CBR of subbase material is estimated to be 40. ✓

4) Surface course is AASHTO #57 stone From Fig 1 CBR of the surface cours is estimated to be about 60.

5) Minimum road section thickness is 16 inches to meet cover requirement.

Golder Associates	SUBJECT East Hide Pile Gravel Access Road		
	Job No. 903-6400 Ref. INDUSTRI-PLEX /WOBURN /MA	Made by DOKL Checked PCN Reviewed PCC PSt	Date 5/19/92 Sheet 3 of 4

Calculations = 1) Maximum weight of truck and its cargo is 8 tons.

$$\text{wheel load} = \frac{8 \times 2000 \frac{lb}{ton}}{4 \text{ wheel}} = 4000 \text{ lb.}$$

2) Required subbase thickness

For subgrade with CBR of 15

From Fig 1, the minimum subbase thickness is 5.5 in ≈ 6 inches. ✓

3) Required surface course thickness

For subbase with CBR of 40.

From Fig 1, the minimum surface course thickness is 3 inches ✓

4) Minimum required section thickness is 16 inches

∴ Use 13 inches of road subbase fill under 3 inches of AASHTO #57 surface course.

Use Geotextile to underlie fill section.

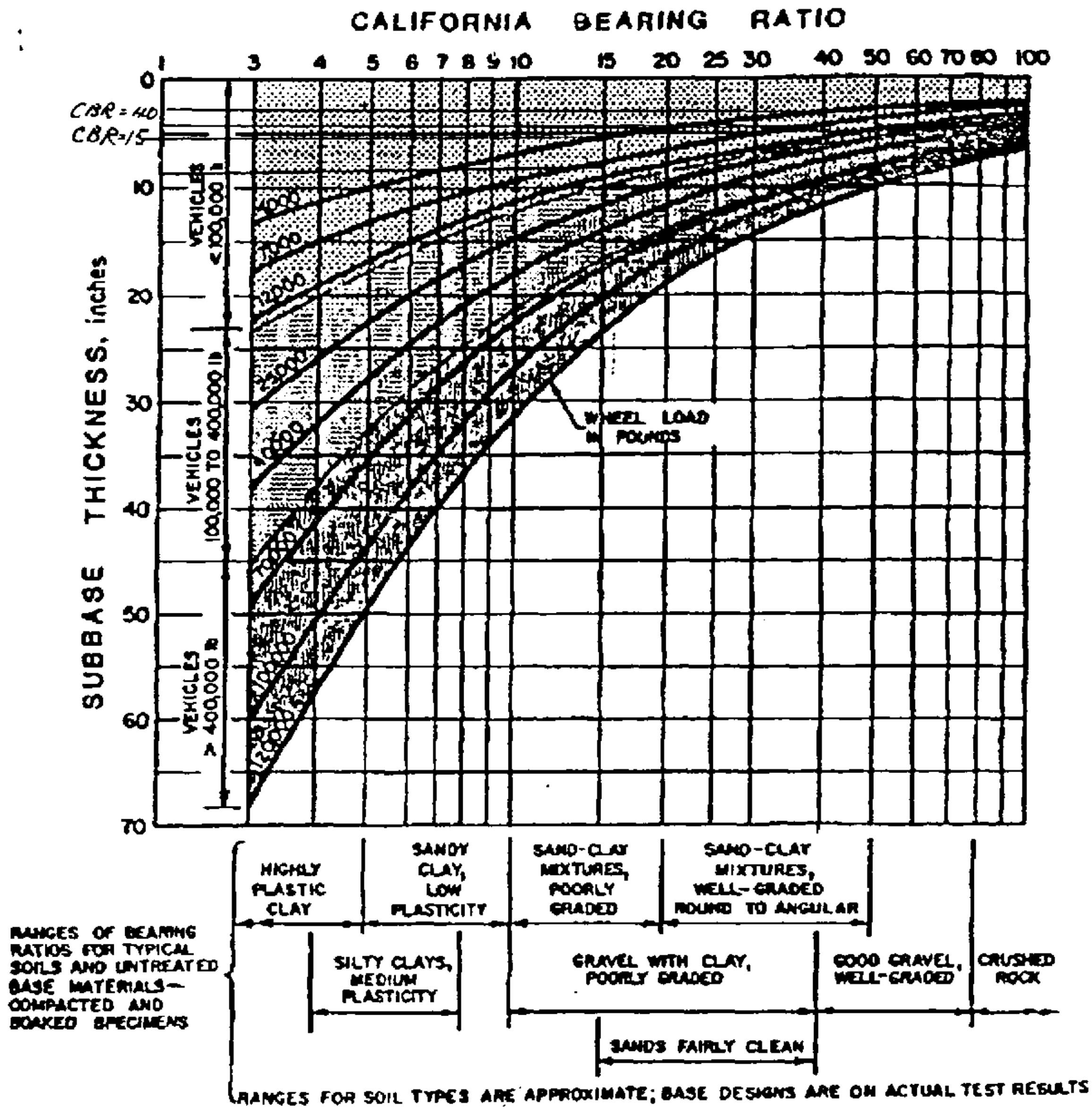


FIGURE 1 - CBR curves.

relation to subgrade characteristics. To be completely accurate, it necessitates CBR tests to precisely determine the bearing capabilities of both subgrade and subbase materials. These tests can be conducted by a soil-testing laboratory at relatively minimal cost simply by submitting samples of the subgrade and subbase materials.

The curves of figure 18 depict subbase thickness requirements for a wide range of CBR test values. To serve as a general indication of the subbase thicknesses required for various subgrade soil types, ranges of bearing ratios

CHAPTER 13

STREAM AND WETLAND SEDIMENTS REMEDIATION

TABLE OF CONTENTS

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CHAPTER 13
STREAM AND WETLAND SEDIMENTS REMEDIATION

13.1 INTRODUCTION

This chapter outlines the remedial actions selected for the stream and wetland sediments which contain Arsenic, Lead and/or Chromium above Consent Decree Action Levels within the boundaries of the Site.

Wetlands within the project Site were delineated and described in a previous report by Wetlands Management Specialists, Inc. (WMS, 1986). Figure 13-1 shows the Wetlands Location Map, reproduced from Figure 1 of the WMS report, and the present Site boundary. The WMS report covered a study area larger than the present Site and identified the wetlands with numbers from one through nine. Some of the wetlands were further designated with suffixes A, B, C, etc. Thirteen of the wetlands shown on Figure 1 of the WMS report are located within the present Site limits. These are: 1C, 2A, 2B, 3A, 3B, 3C, 3D, 3E, 7A, 7B, 7C, 8, and part of 6A.

13.2 REMEDIAL DESIGN WORK PLAN REQUIREMENTS

The Remedial Design Work Plan (RDWP; Golder, 1990) requires the 100% Design Report to provide the following information:

> "Development of final sediment excavation methodology, sections for wetlands revitalization, additional remediation and/or revitalization techniques, and monitoring plan" (p. 57)

In accordance with this requirement, this chapter discusses the remedial actions for each specific stream and wetland for which the sediments need to be remediated and the associated designs for the remediation are provided. Mitigation of wetlands impacts due to sediment remediation is discussed in Chapter 14.

13.3 CONSENT DECREE REQUIREMENTS

The Consent Decree (USEPA, 1989a) briefly explains the work to be performed and establishes in the RDAP the requirements for remediation of sediments. Sediments within streams and wetlands where there are "no odor-emitting Hazardous Substances (e.g. hide wastes),...shall dredge the Hazardous Substances or remove them by another method shown to be environmentally protective and approved by the EPA in consultation with the Commonwealth" (p. 5).

The RDAP mandates an in-situ cover for areas with sediments containing Arsenic, Lead, and/or Chromium at or above Consent Decree action levels, and hide residues, stipulating that these capping activities will be consistent with other technical requirements of the RDAP (p.6).

Following the criteria described above and the extent of Arsenic, Lead and/or Chromium above Consent Decree action levels shown in Sheets 11-2A through 2D, seven of the WMS-delineated wetlands (1C, 2A, 3B, 7A, 7B, 7C, and 8) have sediments that require remediation. In order to refine the extent of remediation in Wetlands 3B and 8, a limited program of supplementary sediment sampling was carried out in June 1991 and the results are presented as Appendix 13-A. In addition to these seven wetlands there are two channels in which the sediments also must be remediated. These are the New Boston Street Drainway, including the culverted portion and the channel connecting the culvert to Wetland 8, and the channel draining into the New Boston Street Drainway from the west.

Although Wetland 3B does include some sediment containing lead in excess of ROD action levels, remediation of this wetland is not to occur at the specific direction of the USEPA (USEPA letter dated March 4, 1992 to ISRT).

The nine streams and wetlands with sediments that are to be remediated are shown on Sheet 13-1. The guidelines for the remediation of the stream and wetland sediments are discussed in the following sections.

Finally, the RDAP requires that excavated sediments be "consolidated in other areas of the Site which contain such Hazardous Substances and which will be covered as part of the approved remedial action" (p. 5).

13.4 STREAM SEDIMENTS REMEDIATION

This section discusses the guidelines for remediation of stream sediments. Wetlands 2A and 7C that are elongated in shape and have flow patterns typical of streams are also included in this section. Including these two wetlands, the streams that require sediment remediation are:

- The Western Branch of the Aberjona River (Wetland 2A);
- The Atlantic Avenue Drainway (Wetland 7C);
- The New Boston Street Drainway, including the culverted portion and the channel connecting the culvert to Wetland 8; and
- The channel draining into the New Boston Street Drainway from the west.

Additionally, the culverts associated with the Western Branch of the Aberjona River, the Atlantic Avenue Drainway, and the New Boston Street Drainway will be cleaned.

13.4.1 Remediation Requirements for Stream Sediments

The streams on the Site have several functions. These functions are the collection of stormwater from surrounding drainage areas, the conveyance of stormwater from upstream, and the storage of backwaters during a storm.

The remedy for streams sediments must allow satisfactory performance of these functions. Additionally, the following criteria were considered in the selection of the remedy:

- Ability to perform in accordance with their design objectives for a minimum of 30 years;
- Satisfactory performance under varying groundwater conditions and to prevent sediment transport via groundwater seepage toward the stream;

- Prevention of surface water from contacting sediments and, possibly, transporting them downstream;
- Minimization of storage capacity losses;
- Satisfactory performance under variable weather conditions;
- Maintenance of discharge capacity so that peak discharges can be conveyed without increasing the flood potential;
- Prevention of erosion;
- Minimization of excavation of hide residues; and,
- Continued ability to collect runoff from the surrounding drainage areas.

13.4.2 Selected Remedies

The first stream sediment remedy, for streams containing Arsenic, Lead and/or Chromium at or above Consent Decree action levels, in the absence of hide residues, consists of a gravel/cobble cap to be placed after dredging the sediments. A minimum of 16 inches of sediments, is to be dredged followed by placement of a 16 ounce nonwoven geotextile and a 16 inch gravel/cobble cap with a d_{50} of 3 inches (see Detail C on Sheet 13-2). This remedy has been selected for the channel draining into the New Boston Street Drainway from the west, the northern portion of the New Boston Street Drainway, and the Atlantic Avenue Drainway. Although the northern portion of the New Boston Street Drainway and the channel draining from the west contain some hide residues, this remedy is being applied to these streams under the direction of the USEPA in order to minimize impacts upon this portion of the industrial park. The Atlantic Avenue Drainway has also been determined to contain hide residues at some locations, but will also receive this remediation in order to preserve its current hydrologic conditions and allow it to function as the recharge basin. The design for the Atlantic Avenue Drainway is presented in Chapter 9.

The second stream sediment remedy, for streams containing Arsenic, Lead and/or Chromium at or above Consent Decree action levels and hide residues, utilizes the same cover but with the minimum amount of dredging consistent with maintaining storm flow capacity. The decision to dredge hide residues in this manner was made to comply with requests from the Agencies. The cover in such locations will comprise a 16 ounce non-woven geotextile overlain by a 16 inch thick gravel/cobble cap. This remedy will be implemented in the following areas:

- The western portion of the Western Branch of the Aberjona River (Wetland 2A); and,
- The portion of the New Boston Street Drainway adjacent to Wetland 8.

The gravel/cobble lined channels are to have a minimum base width of 4 feet and side slopes of one to one or flatter. The base width of each channel is indicated in Sheet 13-1. At locations where the gravel/cobble lined channels will connect to culverts, transition sections have been incorporated to match the designed channel bottom width to the dimensions of the culvert (see Detail 1 on Sheet 13-3). These transition sections are 6 feet in length and maintain the channel's one to one side slope. Six foot long transitions have also been designed to smoothly vary the channel width when required (see Detail 1 on Sheet 13-2). Transitioning between gravel/cobble lined streams and existing stream beds has been provided (see Detail 2 on Sheet 13-3).

The third stream sediment remedy consists of culvertization. This remedy has been selected only for the portion of the Western Branch of the Aberjona River adjacent to the East Central Hide Pile where regrading of the hide pile slope, for stabilization reasons, does not allow other solutions. A 24 inch diameter reinforced concrete pipe will be bedded in a 6 inch minimum layer of AASHTO No. 57 coarse aggregate, and backfilled with previously excavated material (see Detail 4 on Sheet 13-3).

The fourth stream sediment remedy selected is the cleaning, by means of flushing, of culverts connecting channels which require remediation.

Table 13-1 summarizes these remedies as applied to the stream sediments requiring remediation.

13.5 WETLAND SEDIMENTS REMEDIATION

The wetlands in which sediment remediation is to be undertaken are 1C, 7A, 7B and 8, as identified on Sheet 13-1. For these wetlands, there are two possible situations. First, where Arsenic, Lead and/or Chromium concentrations exceed Consent Decree action levels in the absence of hide residues, the sediments will be dredged to a depth of 16 inches and a permeable cap placed. The permeable cap will consist of a 16 ounce nonwoven geotextile at the bottom of the excavation followed by 8 inches of gravel to discourage animal burrows, and 8 inches of topsoil, meeting the wetlands mitigation requirements presented in Chapter 14. The area to be dredged will be determined by the extent of standing water at the time of dredging plus an additional approximate 10-foot strip around the wetland above the water level. An additional area may need to be dredged for construction practicality and, in some locations, above grade capping around the dredged area may be required as part of the permeable cover. This remedy will be used for part of Wetland 1C.

Second, where Arsenic, Lead and/or Chromium exceed Consent Decree action levels and hide residues were found, a 16 inch thick permeable cap will be placed over the sediments; this remedy will be used for part of Wetland 1C and for Wetland 8. For the part of Wetland 1C, the permeable cap will consist of a 16 ounce nonwoven geotextile placed on the sediments, followed by 8 inches of gravel to discourage animal burrows, and a 8 inch layer of topsoil, meeting the wetlands mitigation requirements of Chapter 14. For Wetland 8 the permeable cap will consist of a 16 ounce nonwoven geotextile placed on the sediments, followed by a 12 inch soil cover with a 4 inch thick topsoil layer. The prevention of animal burrows in Wetland 8 is not a remediation goal, because this shallow wetland will be completely eliminated by the covering required by the Consent Decree (see Chapter 14).

In all cases, at specific locations where velocities or wave action may cause erosion, gravel/cobble protection has been included in the design.

The Chromium Lagoons (Wetlands 7A and 7B) will be filled completely due to the high metal concentrations and hide residues present, and their low wetland value. The filled lagoons will then be capped with a permeable cover meeting the requirements of Chapter 11.

Transitions between remediated and nonremediated sections of the wetlands have been designed (see Sheet 13-4). In areas where remediation has caused an elevation difference between areas in the wetlands, a 10 percent slope grade change will be incorporated.

The excavation of animal burrows in the permeable cover within Wetlands 1C will be discouraged by the use of gravel in the cover as follows. An 8 inch layer of gravel will be placed directly on the geotextile and covered with appropriate soil to provide a total cover thickness of 16 inches. This gravel medium will also be placed in a 10 foot wide skirt around the perimeter of the area undergoing remediation. This gravel barrier will inhibit burrowing by the mammals, reptiles, and amphibians expected to inhabit the remediated wetlands.

Table 13-2 summarizes these three remedies as applied to the wetland sediments requiring remediation and details are presented on Sheet 13-4.

13.6 RELATED STRUCTURES

In addition to the specific remediation designs, additional structures have been designed to supplement stormwater management. These additional structures are used to regulate and channel stormwater through the Site. The structures are as follows:

- Extension of the Atlantic Avenue Drainway;
- Channel connecting Wetland 1C and the Wetland Creation Area;
- Multi-stage stormwater outflow structure;
- Roadway culverts; and,
- Stormwater holding areas.

The extension of the Atlantic Avenue Drainway has been created in order to maintain a positive outflow from the created wetland area and to assist in the management of storm flows. This extension will connect the created wetland area to the existing Atlantic Avenue Drainway (see Sheet 13-1). The extension will have a 3 foot bottom width and one to one side slopes (see Detail D on Sheet 13-2).

The channel connecting Wetland 1C and the Wetland Creation Area will supply surface water to the created wetland area and provide a corridor for wildlife. The channel will have a 4 foot bottom width with 2H:1V side slopes. Lining the channel will be a 16 inch gravel/cobble layer with a d_{50} of 3 inches. Underlying the gravel/cobble lining will be 16 ounce non-woven geotextile. Underlying the 16 ounce non-woven geotextile will be a 6 inch thick layer of silty clay loam to enhance surface water retention in the wetland creation area.

A multi-stage stormwater outflow structure will control the outflow from the created wetland area (see Detail 1 on Sheet 13-5). The structure will act to detain peak storm flows in the created wetland area, and is designed to allow some manipulation of water levels during initial establishment of the wetland. When a suitable wetland hydrology has been established, the outflow levels will be permanently fixed.

Modifications to the Site grading have made it necessary to design culverts to transfer stormwater at some locations. All culverts have been designed with prefabricated flared end sections (see Detail 2 on Sheet 13-5) to improve their hydraulics at the entrance and exits. Culvert exits have also been designed with rip-rap aprons to protect against erosion.

Three areas will be excavated to hold stormwater (see Sheets 13-1 and 13-6). These areas have been created to help balance the stormwater storage losses resulting from the remediation. The stormwater holding areas will also contain additional storm runoff that will be generated from areas of the Site where soils are being covered with asphalt. These holding areas will be excavated with three to one side slopes and vegetated to prevent erosion. Discharges from the holding areas will be directed to either the New Boston Street Drainway, the storm sewer in New Boston Street, or to the storm sewer leading to the channel adjacent to Wetland 8. The design of these stormwater storage areas is conceptual and will be confirmed upon review of the conditions existing at the time of remediation.

13.7 EXCAVATION TECHNIQUES

The excavation techniques for the stream sediments will entail the use of either a backhoe or a dragline. The excavation techniques for the wetland sediments may involve the use of suction dredging, backhoe, or a dragline. The method will depend upon factors such as the standing water area at the time of excavation in relation to the reach of the equipment and contractor's preference.

The excess water in the sediments will be removed prior to placement of the sediments in other areas of the Site that will receive permeable cover. Dewatering of the sediments will be achieved by an approved method so that the compaction performance specification may be attained.

During the excavation of sediments potentially containing hide residues, odor control techniques outlined in Section 01563 of the Specifications will be implemented.

13.8 CONCLUSION

The Consent Decree, via the RDAP, establishes the requirements for the remedies for the stream and wetland sediments. The results of the application of these criteria are the remedial actions discussed within this chapter.

The main sediments remedy selected for the streams consists of dredging and capping with a gravel/cobble cover. When the main remedy is not applicable because other conditions prevail, the alternative culvertization has been designed. Cleaning of existing culverts adjacent to remediated streams has also been included as part of the remedy.

The remedies selected for the various wetlands are:

- Dredging and capping;
- Capping; and
- Filling and capping.

REFERENCES

Golder Associates Inc., 1990. Remedial Design Work Plan, Industri-Plex Site, Woburn, MA, July.

USEPA, see U. S. Environmental Protection Agency.

U. S. Environmental Protection Agency, 1989a. Industri-Plex Site Consent Decree, Civil Action 89-01960MC, April.

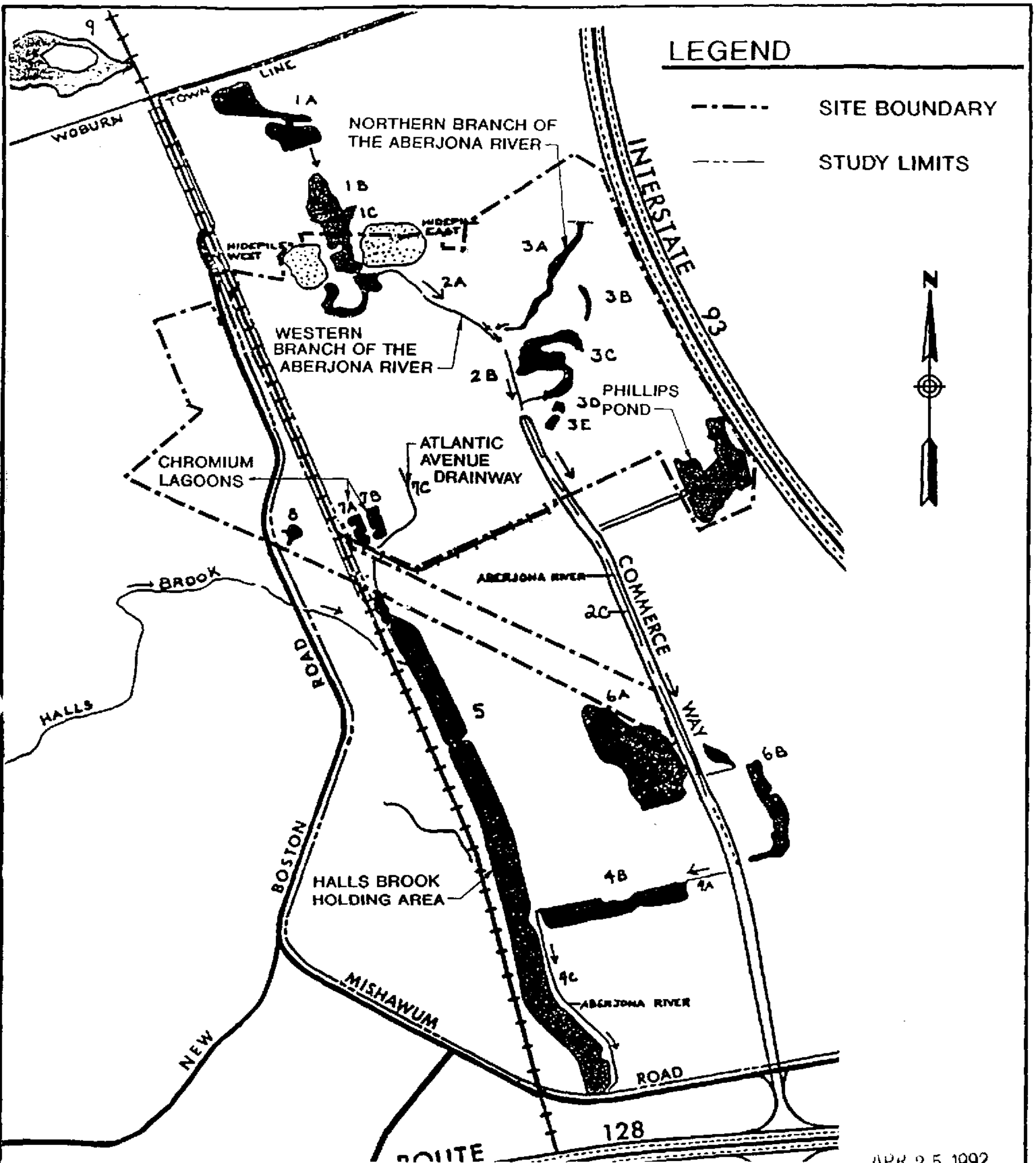
Wetlands Management Specialists, 1986. Floodplain and Wetlands Assessment, Woburn Industri-Plex 128, Superfund Site, Woburn, Massachusetts.

TABLE 13-1 SUMMARY OF STREAM SEDIMENTS REMEDIATION

NAME OF WATERBODY	CHANNEL TYPE	PRELIMINARY REMEDIATION
Atlantic Avenue Drainway (Wetland 7C)	Man-made	Dredge the upper 16 inches and place a gravel/cobble cover
New Boston Street Drainway	Man-altered	Dredge the upper 16 inches and place a 16 inch gravel/cobble cover in the northern portion of the New Boston Street Drainway, and limited dredging and placement of a 16 inch gravel/cobble cover for the portion adjacent to Wetland 8
Channel draining into New Boston Street Drainway from the west	Man-altered	Dredge the upper 16 inches and place a gravel/cobble cover
Western Branch of Aberjona River (Wetland 2A)	Man-made	Limited dredging and placement of a 16 inch gravel/cobble cover in the western portion; place a hydraulically sized concrete culvert in the eastern portion

TABLE 13-2 SUMMARY OF WETLAND SEDIMENTS REMEDIATION

NAME OF WATERBODY	TYPE	PRELIMINARY REMEDIATION
Wetland 8	Natural	Place an above grade permeable cap
Wetland 1C	Man-altered	Dredge a minimum of 16 inches and place an at grade permeable cap in areas with metals at or above Consent Decree action levels. Place an above grade permeable cap in areas with metals at or above Consent Decree action levels and hide residues
Chromium Lagoons (Wetlands 7A & 7B)	Man-made	Filling and capping



APR 25 1992

NOTES

1) THIS FIGURE ADAPTED FROM FIGURE 1 OF THE WETLANDS ASSESSMENT REPORT BY WETLAND MANAGEMENT SPECIALISTS, INC., 1986.

2) THIS FIGURE WAS MODIFIED TO SHOW THE PRESENT SITE BOUNDARY.

JOB No.: 903-6400	SCALE: 1" = 800'	WETLANDS LOCATION MAP		
DRAWN: VEEF	DATE: 08/09/91			
CHECKED: VEEF 8/9/91	DWG. No.: MA01-574			
Golder Associates		INDUSTRI-PLEX SITE REMEDIAL TRUST	FIGURE 13-1	

188690

APPENDIX 13-A

Supplementary Sediment Sampling

TABLE OF CONTENTS

1.0 INTRODUCTION

Supplementary sediment sampling was undertaken in order to further refine the extent of arsenic, lead, and chromium above Consent Decree action levels in selected wetlands at the Industri-Plex Site. The samples were also examined for the presence of hide residue. This sampling supplemented previous sampling undertaken as part of Pre-Design Investigation (PDI) Task SW-1 (Golder Associates Inc., 1990).

This report outlines the work which was conducted, presents the results, and documents the data quality assessment. Supporting documents, such as borehole logs, chain of custody forms, and laboratory analyses are included as attachments to this Appendix.

2.0 SUPPLEMENTARY SEDIMENT SAMPLING

All work was conducted in accordance with the Golder Associates Inc. Technical Procedures given in the PDI Field Sampling Plan (Golder Associates Inc., 1989a) included as Attachment A to this Appendix.

Sediment sampling was carried out at five locations in Wetland 3B and two locations in Wetland 8. Sample locations are shown on Sheets 11-2B and 11-2C. Except for location 123, five samples were taken from each borehole in Wetland 3B at the following depths: 0-6 inches, 6-12 inches, 12-18 inches, 18-27 inches, and 27-36 inches. Only the 0-6 inch and 6-12 inch samples were collected at location 123. In Wetland 8, three samples were taken from each borehole at the following depths: 0-6 inches, 6-18 inches and 18-36 inches. The two boreholes in Wetland 8 were used only to assess whether hide residue was present, since extensive metals data was available at this location. Three samples from each borehole were considered sufficient for this purpose. Samples were collected, using a hand auger, by a drilling contractor under the supervision of a Golder Associates field geologist.

Quality Control samples were collected at a rate of one per twenty primary samples, including matrix spikes, matrix spike duplicates, field duplicates and equipment rinsate blanks.

3.0 SAMPLE ANALYSIS AND DATA QUALITY ASSESSMENT

Analyses for arsenic, lead, and chromium were performed by Savannah Laboratories according to SW-846 methods as presented in the PDI Quality Assurance Project Plan (QAPjP, Golder Associates Inc., 1989b). All sediment samples were analyzed microscopically for hide residue in Golder Associates' soils laboratory in Mt. Laurel, New Jersey. The presence or absence of hair fibers in an oven-dried sample was used to determine whether the sample contained hide residue. All instances where hair fibers were detected were confirmed by a second microscopist.

The laboratory results for arsenic, lead, and chromium were assessed in accordance with procedures given in the QAPjP. The results are presented in Table 1. The concentrations of arsenic, lead and chromium were below Consent Decree action levels in all samples collected from Wetland 3B during this task. One sample from borehole 121 contained hide residue in the 0-6 inch depth interval.

Hide residue was also detected in the 6-18 inch depth interval samples from boreholes 135 and 136 in Wetland 8. Analyses for arsenic, lead, and chromium were not performed on these samples because these metals were found above Consent Decree action levels in samples from Wetland 8 collected and analyzed as part of the Remedial Investigation (Stauffer Chemical Co., 1984).

All QC sample results were found to be within control limits specified in the QAPjP.

4.0 REFERENCES

Golder Associates Inc., 1989a. Field Sampling Plan, Pre-Design Investigation, Industri-Plex Site, Woburn, MA, December, 1989.

Golder Associates Inc., 1989b. Quality Assurance Project Plan, Pre-Design Investigation, Industri-Plex Site, Woburn, MA, December, 1989.

Golder Associates Inc., 1990. Pre-Design Investigation Task SW-1, Extent of Hazardous Substances in Wetlands and Surface Water Sediments, Interim Final Report, Industri-Plex Site, Woburn, MA, September, 1990.

Stauffer Chemical Company, 1984. Woburn Environmental Studies, Phase II, Volume 1, Remedial Investigation, August, 1984.

C:95%:SEDSAM

TABLE 1

SUMMARY OF ARSENIC, LEAD, CHROMIUM
AND HIDE RESIDUE ANALYSES

NOTE: Sample ID is designated as described for the example given below.

IP/SW-1/001/006/1/3/1

The first two characters (IP) stand for the Industri-Plex Site;

The third through fifth characters (SW-1) stand for the Pre-Design task number;

The sixth through eighth characters (001) stand for the sample location number within that task (EBA and EBB=equipment rinsate blanks);

The ninth through eleventh characters (006) stand for the depth of the bottom of the sample interval in inches below ground surface, where applicable;

The twelfth character (1) stands for the matrix type (1=solid, 2=liquid, 3=gas);

The thirteenth character (3) stands for the sampling round number (D=field duplicate sample); and

The fourteenth character (1) stands for the analysis type (1=arsenic, lead and chromium).

TABLE 1

SUMMARY OF ARSENIC, LEAD, CHROMIUM AND HIDE RESIDUE ANALYSES - TASK SW-1

INDUSTRI-PLEX SITE   PRE-DESIGN INVESTIGATION   WOBURN, MA   Matrix:SOIL

SampleID	Depth (in.)	Date Sampled (yymmdd)	Arsenic (mg/kg) Result	AC	RL	Lead (mg/kg) Result	AC	RL	Chromium (mg/kg) Result	AC	RL	% Moisture Result	RL	Hide Residue
IP/SW1/120/006/1/3/1	006	910624	<16	U	16	52	A	NR	1.7	A	NR	39	NR	N
IP/SW1/120/012/1/3/1	012	910624	<14	U	14	12	A	NR	3.1	A	NR	27	NR	NE
IP/SW1/120/018/1/3/1	018	910624	<14	U	14	<6.9	U	6.9	6.2	A	NR	28	NR	N
IP/SW1/120/027/1/3/1	027	910624	<13	U	13	<6.6	U	6.6	6.2	A	NR	24	NR	NE
IP/SW1/120/036/1/3/1	036	910624	<12	U	12	<6.2	U	6.2	5.0	A	NR	19	NR	N
IP/SW1/121/006/1/3/1	006	910624	<37	U	37	470	A	NR	37	A	NR	73	NR	Y
IP/SW1/121/006/1/D/1*	006	910624	<33	U	33	480	A	NR	38	A	NR	70	NR	NE
IP/SW1/121/012/1/3/1	012	910624	<13	U	13	<6.6	U	6.6	5.8	A	NR	24	NR	NE
IP/SW1/121/018/1/3/1	018	910624	<13	U	13	<6.3	U	6.3	5.4	A	NR	21	NR	N
IP/SW1/121/027/1/3/1	027	910624	<12	U	12	<6.1	U	6.1	5.5	A	NR	18	NR	NE
IP/SW1/121/036/1/3/1	036	910624	<13	U	13	<6.7	U	6.7	4.7	A	NR	25	NR	N
IP/SW1/122/006/1/3/1	006	910624	<56	U	56	310	A	NR	37	A	NR	82	NR	N
IP/SW1/122/012/1/3/1	012	910624	<48	U	48	38	A	NR	11	A	NR	79	NR	NE
IP/SW1/122/018/1/3/1	018	910624	<26	U	26	17	A	NR	55	A	NR	61	NR	N
IP/SW1/122/027/1/3/1	027	910624	<16	U	16	<8.2	U	8.2	5.6	A	NR	39	NR	NE
IP/SW1/122/036/1/3/1	036	910624	<16	U	16	<8.1	U	8.1	5.7	A	NR	38	NR	N
IP/SW1/123/006/1/3/1	006	910625	<45	U	45	310	A	NR	27	A	NR	78	NR	N
IP/SW1/123/006/1/D/1*	006	910625	<45	U	45	300	A	NR	25	A	NR	78	NR	NE
IP/SW1/123/012/1/3/1	012	910625	<24	U	24	23	A	NR	8.7	A	NR	58	NR	N
IP/SW1/124/006/1/3/1	006	910624	<43	U	43	86	A	NR	24	A	NR	77	NR	N
IP/SW1/124/012/1/3/1	012	910624	<19	U	19	12	A	NR	19	A	NR	48	NR	NE
IP/SW1/124/018/1/3/1	018	910624	<14	U	14	<6.8	U	6.8	8.9	A	NR	26	NR	N
IP/SW1/124/027/1/3/1	027	910624	<14	U	14	<6.8	U	6.8	6.7	A	NR	27	NR	NE
IP/SW1/124/036/1/3/1	036	910624	<13	U	13	<6.4	U	6.4	7.3	A	NR	22	NR	N
IP/SW1/134/006/1/3/1	006	910625	NA		NA	NA		NA	NA		NA	NA	NA	N
IP/SW1/134/018/1/3/1	018	910625	NA		NA	NA		NA	NA		NA	NA	NA	Y
IP/SW1/134/036/1/3/1	036	910625	NA		NA	NA		NA	NA		NA	NA	NA	N
IP/SW1/135/006/1/3/1	006	910625	NA		NA	NA		NA	NA		NA	NA	NA	N
IP/SW1/135/018/1/3/1	018	910625	NA		NA	NA		NA	NA		NA	NA	NA	Y
IP/SW1/135/036/1/3/1	036	910625	NA		NA	NA		NA	NA		NA	NA	NA	N

NOTES: * - Field Duplicate Sample
RL - Reporting Limit
NA - Not Applicable
NR - Not Reported

AC - Assessment Codes..
A - Quantitative Data
J - Estimated (Semiquantitative) Data
UJ - Not Detected/Semiquantitative Data
R - Unusable Data
U - Not Detected/Quantitative

Hide Residue Detected.......................
Y - Detected
N - Not Detected
NS - Not Sampled
NA - Not Applicable
BS - Background Sample
NE - Not Examined

TABLE 1

SUMMARY OF ARSENIC, LEAD, CHROMIUM AND HIDE RESIDUE ANALYSES - TASK SW-1

INDUSTRI-PLEX SITE PRE-DESIGN INVESTIGATION WOBURN, MA Matrix:AQUEOUS

SampleID	Depth (in.)	Date Sampled (yymmdd)	Arsenic (mg/L)			Lead (mg/L)			Chromium (mg/L)			% Moisture		Hide Residue
			Result	AC	RL	Result	AC	RL	Result	AC	RL	Result	RL	
IP/SW1/EBA/000/2/3/1	000	910624	<0.10	U	0.10	<0.050	U	0.050	<0.010	U	0.010	NA	NA	NA
IP/SW1/EBB/000/2/3/1	000	910625	<0.10	U	0.10	<0.050	U	0.050	<0.010	U	0.010	NA	NA	NA

NOTES: * - Field Duplicate Sample
RL - Reporting Limit
NA - Not Applicable
NR - Not Reported

AC - Assessment Codes....
A - Quantitative Data
J - Estimated (Semiquantitative) Data
UJ - Not Detected/Semiquantitative Data
R - Unusable Data
U - Not Detected/Quantitative

Hide Residue Detected....
Y - Detected
N - Not Detected
NS - Not Sampled
NA - Not Applicable
BS - Background Sample
NE - Not Examined

ATTACHMENT A

Technical Procedures

1.0 PURPOSE

This Technical Procedure is to be used to establish uniform methods of sampling of surface soils. Provisions are made for analyses and recording of data.

2.0 APPLICABILITY

This Technical Procedure is applicable to personnel sampling surface soils for chemical analyses.

3.0 DEFINITIONS

3.1 Surface Soil: Any soils that are on the land surface or are exposed by hand digging or boring within five (5) feet of the land surface.

3.2 Sampling Interval: The depth interval which the soil sample represents.

3.3 In Situ Soils: Soils that are in place within the soil column.

4.0 REFERENCES

4.1 U.S. EPA, 1982 (updated 1984). Test Methods for Evaluating Solid Waste: Physical/Chemical Methods: SW-846. Office of Solid Waste and Emergency Response. Washington, D.C.

5.0 DISCUSSION

5.1 None

6.0 RESPONSIBILITY

6.1 Sampling Technician: Responsible for completing the assigned sampling in accordance with this Technical Procedure.

6.2 Task Leader: Responsible for determining the soils to be sampled and ensuring that sampling procedure and sample documentation are in accordance with this procedure and applicable project plans.

6.3 Project Manager: Responsible for determining the type of chemical analyses to be performed on the soil samples.

7.0 EQUIPMENT AND MATERIALS

7.1 Site map, map board and/or clipboard.

7.2 Field notebook or Field Report forms (Exhibit A).

7.3 Assorted standard field equipment (e.g., hammers, post-hole digger, shovel, hand auger) for exposing soils to be sampled.

7.4 Measuring tape.

7.5 Engineers rule (minimum 6 feet long, with 0.10 foot graduations).

7.6 Indelible ink pens.

7.7 Two inch wood stakes and flagging material.

7.8 Sampling equipment appropriate for soils to be analyzed for non-volatile constituents. All such equipment shall be metal (steel, stainless steel or aluminum) and includes split spoon samplers, hand augers, hand scoops, sampling thiefs or sampling tiers (see reference 4.1 for details on sampling equipment).

7.9 If volatile constituents are to be analyzed in the soil samples, the sampling equipment shall be designed to minimize exposure to the atmosphere. A metal drive tube appropriate for the size of the soil particles shall be used.

7.10 Sample bottles, size commensurate with the desired sample and soil particle size.

7.11 Chain-of-Custody Records and seals.

7.12 Sample Integrity Data Sheets (Exhibit B).

7.13 Carbon paper, if necessary.

7.14 Decontamination solutions such as organic free distilled/deionized water, non-phosphate detergent, tap water, methanol (for organic analytes), nitric acid (for metal analytes).

7.15 Decontamination equipment such as brushes, sprayers and containers for capturing waste solutions.

7.16 Sample labels.

8.0 PROCEDURE

8.1 The sample location will have been surveyed and marked with a wooden stake, labeled with the boring number, prior to sampling.

8.2 Relevant sampling events, including on-site personnel and visitors, shall be recorded on the Field Report forms (Exhibit A) in triplicate. Events shall be recorded chronologically with the time of each event noted.

8.3 All sampling equipment (split spoons, hand augers, drive tubes, etc.) shall be decontaminated before and after each use. Hollow stem auger flights shall be steam cleaned prior to use at each sample location. The sampling equipment will be washed with non-phosphate detergent solution. Brushes shall be used to aid in removing all visible soil grit. A tap water rinse will be used to thoroughly removal all detergent solution. If trace metals are of interest, rinse three times with distilled water, followed by a rinse with 10 percent trace-metal analysis grade nitric acid, followed by another triple rinse of distilled water. If organics are to be analyzed, a final step is required, consisting of an HPLC-grade methanol rinse followed by a triple rinse with distilled water. The methanol should be allowed to evaporate before a final rinse with distilled water. All rinseate shall be captured and contained for proper disposal. Responsibility for disposal shall be as identified in the project plans.

8.4 The soils to be sampled will be exposed prior to sample acquisition. If the upper six inches of soils are to be sampled, then surface vegetation shall be removed. If samples are to represent discrete depth intervals below land surface then overlying soils shall be removed by a shovel, post-hole digger or hand auger to the desired interval.

8.5 A soil sample of in-situ materials shall be obtained from the desired sampling interval. If analytes are not volatile, an in-situ soil sample can be obtained from the desired sampling interval using the most convenient equipment such as: a hand scoop, hand auger, sampling (thief) or tier, whichever is most suitable for obtaining in-situ soils. The soils shall be visually inspected and immediately put into the appropriate sample bottle. No preservatives shall be added to the sample.

8.6 If analytes are volatile, the in-situ soil sample shall be obtained from the desired sampling interval using a drive tube sampler. Contact between the atmosphere and the sample must be minimized. The drive tube sampler shall be driven into the materials with a hammer.

8.7 Materials shall be transferred from the sampler directly to the sample container using spatulas (plastic for metals analysis, stainless steel or aluminum for organics). Special care should be taken to avoid sample contact with other materials. An air-tight cap shall be placed immediately on the sample bottle. No preservatives shall be added to the sample.

8.8 If soil sample composites are to be established, equal volumes of individual samples will be added together for the composite sample. The composite sample will be given an individual sample number and the sample number of each added sample (compositing the composite sample) will be recorded on the Sample Integrity Data Sheet (Exhibit B). Locations of the individual samples are recorded on the base map.

8.9 Samples are immediately labeled and relevant data recorded on the Sample Integrity Data Sheet for each sample. Site-specific details regarding labeling and recording shall be provided in the project QA plan.

8.8 Samples shall be placed in a cold cooler (about 4°C) as soon as possible and the temperature of the cooler shall be recorded on the Sample Integrity Data Sheet. The cooler of samples shall be within view of the Golder Geologist/Hydrogeologist at all times or in locked storage. A Chain-of-Custody Record shall be filled out and maintained as specified in the project QA plan.

8.9 Samples sent or delivered to the chemical analytical laboratory shall be transferred in accordance with the project QA plan. The original Chain-of-Custody Record shall accompany the samples to the laboratory.

8.10 Any hole made to obtain samples shall be backfilled with soil materials removed from the hole, unless the hole collapses.

8.11 Field Report forms (Exhibit A) shall be prepared by the Golder Geologist/Hydrogeologist to record daily sampling activities. The Field Report forms shall follow chronological format and include the time of each event documented. The base map shall be used to record each sampling location by the Golder Field Engineer/Geologist. Sample Integrity Data Sheets shall be used to record information regarding soil samples that will be chemically analyzed. Chain-of-Custody Records shall be used to record the custody and transferal of samples.

8.11.1 Field records shall be made in triplicate at the work site and the originals (except Chain-of-Custody Records) shall be transmitted to the home office on a daily basis. A copy shall be given to the Task Leader and the Golder Geologist/Hydrogeologist shall retain the other copy for reference.

8.11.2 All copies of field records (including original base map and chain-of-custody record) shall be hand delivered to the home office upon completion of the field activity.

Exhibit B

SAMPLE INTEGRITY DATA SHEET

Plant/Site ________________________ Project No. ____________

Site Location ______________________ Sample ID ____________

Sampling Location ______________________________________

____

Technical Procedure Reference(s) __________________________

Type of Sampler ____

Date ____________________ Time ________________________

Media ___________________ Station ______________________

Sample Type: grab time composite space composite

Sample Acquisition Measurements (depth, volume of static well water and purged water, etc.

____

____

____

Sample Description ______________________________________

____

____

Field Measurements on Sample (pH, conductivity, etc.) __________

____

____

____

Aliquot Amount Container Preservation/Amount

____

____

____

____

____

____

____

____

____

Sampler (signature) ______________________ Date ______________

Supervisor (signature) ____________________ Date ______________

Golder Associates Inc.

ATTACHMENT B

Borehole Logs

BOREHOLE LOG SW-1/120

PROJECT: Industri-Plex Site Pre-Design Investigation **DATE:** 06/24/91
SURFACE ELEV: 64.8 **DATUM:** NGVD (1929)
DRILLING METHOD: Hand Auger **LOCATION:** N:554254.8 E:697853.8

SAMPLE LOCATION	DEPTH INCHES	SOIL DESCRIPTION
1	0.0 – 6.0	Brown fine SAND and SILT (SM). Large amount of organic material.
2	6.0 – 12.0	Brown coarse to fine SAND with some silt (SM).
3	12.0 – 18.0	Orange-brown coarse to medium SAND, some silt (SM).
4	18.0 – 26.0	Orange-brown coarse to fine SAND, trace silt (SP).
5	26.0 – 36.0	Brown coarse to fine SAND, trace silt (SP).

Depth scale (inches): 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0, 22.0, 24.0, 26.0, 28.0, 30.0, 32.0, 34.0, 36.0

Job No. 893-6255 GOLDER ASSOCIATES INC. Logged: D. Ley
Checked: B. Glazier

BOREHOLE LOG SW-1/121

PROJECT: Industri-Plex Site Pre-Design Investigation **DATE:** 06/24/91
SURFACE ELEV: 63.1 **DATUM:** NGVD (1929)
DRILLING METHOD: Hand Auger **LOCATION:** N:554267.5 E:697799.0

SAMPLE LOCATION	DEPTH INCHES	SOIL DESCRIPTION
1	0.0 – 6.0	Medium to dark brown, fine to medium SAND and SILT (SM). Large amount of organic matter.
2	6.0 – 12.0	Grey-brown, coarse to fine SAND, trace silt, trace of organic matter (SP).
3	12.0 – 18.0	Grey coarse to fine SAND, trace silt, abundant muscovite flakes (SP).
4	18.0 – 26.0	Grey coarse to fine SAND, trace silt (SP).
5	26.0 – 36.0	Grey-brown, coarse to fine SAND, trace silt (SP).

Depth scale (inches): 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0, 22.0, 24.0, 26.0, 28.0, 30.0, 32.0, 34.0, 36.0

Job No. 893-6255 **GOLDER ASSOCIATES INC.** **Logged:** D. Ley
Checked: B. Glazier

BOREHOLE LOG SW-1/122

PROJECT: Industri-Plex Site Pre-Design Investigation **DATE:** 06/24/91
SURFACE ELEV: 63.1 **DATUM:** NGVD (1929)
DRILLING METHOD: Hand Auger **LOCATION:** N:554321.4 E:697794.7

SAMPLE LOCATION	DEPTH INCHES	SOIL DESCRIPTION
1	0.0 – 6.0	Brown fine SAND and SILT (SM), large amount of organic matter.
2	6.0 – 12.0	Brown, fine SAND and SILT (SM), large amount of organic matter.
3	12.0 – 18.0	Brown fine to medium SAND and SILT (SM).
4	18.0 – 26.0	Grey-brown, coarse to fine SAND, little silt (SP).
5	26.0 – 36.0	Grey-brown, coarse to fine SAND, trace silt (SP).

Job No. 893-6255 **GOLDER ASSOCIATES INC.** **Logged:** D. Ley
Checked: B. Glazier

BOREHOLE LOG SW-1/123

PROJECT: Industri-Plex Site Pre-Design Investigation **DATE:** 06/25/91
SURFACE ELEV: 64.1 **DATUM:** NGVD (1929)
DRILLING METHOD: Hand Auger **LOCATION:** N:554291.1 E:697743.9

SAMPLE LOCATION	DEPTH INCHES	SOIL DESCRIPTION
1	0.0 – 6.0	Brown fine SAND and SILT (SM). Large amount of organic matter.
2	6.0 – 12.0	Brown fine SAND and SILT (SM). Large amount of organic matter.
3	12.0 – 18.0	Not sampled.
4	18.0 – 26.0	Not sampled.
5	26.0 – 36.0	Not sampled.

Depth scale: 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0, 22.0, 24.0, 26.0, 28.0, 30.0, 32.0, 34.0, 36.0

Job No. 893-6255 **GOLDER ASSOCIATES INC.** **Logged:** D. Ley
Checked: B. Glazier

BOREHOLE LOG SW-1/124

PROJECT: Industri-Plex Site Pre-Design Investigation **DATE:** 06/24/91
SURFACE ELEV: 63.6 **DATUM:** NGVD (1929)
DRILLING METHOD: Hand Auger **LOCATION:** N:554421.1 E:697819.1

SAMPLE LOCATION	DEPTH INCHES	SOIL DESCRIPTION
1	0.0 – 6.0	Brown fine to medium SAND and SILT (SM). Large amount of organic matter.
2	6.0 – 12.0	Brown fine to medium SAND and SILT (SM).
3	12.0 – 18.0	Grey coarse to fine SAND, trace silt (SP).
4	18.0 – 26.0	Grey-brown coarse to fine SAND, trace silt (SP).
5	26.0 – 36.0	Grey coarse to fine SAND, trace silt (SP).

Depth scale: 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0, 22.0, 24.0, 26.0, 28.0, 30.0, 32.0, 34.0, 36.0

Job No. 893-6255 **GOLDER ASSOCIATES INC.** **Logged:** D. Ley
Checked: B. Glazier

BOREHOLE LOG SW-1/135

PROJECT: Industri-Plex Site Pre-Design Investigation **DATE:** 06/25/91
SURFACE ELEV: 59.0 **DATUM:** NGVD (1929)
DRILLING METHOD: Hand Auger **LOCATION:** N:552346.1 E:695721.0

SAMPLE LOCATION	DEPTH INCHES	SOIL DESCRIPTION
1	0.0 – 6.0	Dark brown fine SAND and SILT (SM) with root mass.
2	6.0 – 18.0	Brown fine SAND and SILT (SM) with root mass.
3	18.0 – 36.0	Grey-brown, coarse to fine SAND, some silt (SP).

Depth scale: 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0, 22.0, 24.0, 26.0, 28.0, 30.0, 32.0, 34.0, 36.0

Job No. 893-6255 **GOLDER ASSOCIATES INC.** **Logged:** D. Ley
Checked: B. Glazier

BOREHOLE LOG SW-1/136

PROJECT: Industri-Plex Site Pre-Design Investigation **DATE:** 06/25/91
SURFACE ELEV: 58.9 **DATUM:** NGVD (1929)
DRILLING METHOD: Hand Auger **LOCATION:** N:552289.9 E:695853.0

SAMPLE LOCATION	DEPTH INCHES	SOIL DESCRIPTION
1	0.0 – 6.0	Dark brown fine SAND and SILT (SM).
2	6.0 – 18.0	Dark brown fine SAND and SILT (SM). Possibly hide residue present, strong hide odor.
3	18.0 – 36.0	Dark brown fine SAND and SILT (SM). Strong hide odor.

Depth scale: 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0, 22.0, 24.0, 26.0, 28.0, 30.0, 32.0, 34.0, 36.0

Job No. 893-6255 **GOLDER ASSOCIATES INC.** **Logged:** D. Ley
Checked: B. Glazier

ATTACHMENT C
Chain of Custody Forms

SL SAVANNAH LABORATORIES AND ENVIRONMENTAL SERVICES, INC.
ANALYSIS REQUEST AND CHAIN OF CUSTODY RECORD

Savannah Division
5102 LaRoche Avenue
Savannah, GA 31404
Phone: (912) 354-7858

JOB NO.:
P.O. NO.:
PROJECT NAME: Industri-Plex Site
PAGE 1 OF 4

CLIENT NAME: Golder Associates Inc
TELEPHONE: 609-273-1110
CLIENT ADDRESS: 20,000 Horizon Way, #500, Mt Laurel, NJ 08054
CLIENT PROJECT MANAGER: Bob Glazier

STANDARD ☐
RUSH ☒
DATE REPORT REQUESTED: 7/14/91

REQUIRED ANALYSES

SAMPLING DATE	SAMPLING TIME	SAMPLE ID	AQUEOUS MATRIX	NONAQUEOUS MATRIX	As, Pb, Cr SW-846									REMARKS
6-24-91		IP/SW-1/120/006/1/3/1		X	X									
↓		IP/SW-1/120/012/1/3/1		X	X									
		IP/SW-1/120/018/1/3/1		X	X									
		IP/SW-1/120/027/1/3/1		X	X									
		IP/SW-1/120/036/1/3/1		X	X									
		IP/SW-1/121/006/1/3/1		X	X									
		IP/SW-1/121/012/1/3/1		X	X									
		IP/SW-1/121/018/1/3/1		X	X									
		IP/SW-1/121/027/1/3/1		X	X									

RELINQUISHED BY: (SIGNATURE)	DATE/TIME	RECEIVED BY: (SIGNATURE)	DATE/TIME	RELINQUISHED BY: (SIGNATURE)	DATE/TIME
Robert M Glazier	6-25-91 1430				
	DATE/TIME	RECEIVED BY: (SIGNATURE)	DATE/TIME	RELINQUISHED BY: (SIGNATURE)	DATE/TIME

LABORATORY USE ONLY — Fed EX Airbill No. 7748886342

RECEIVED FOR LABORATORY BY: (SIGNATURE)	DATE/TIME	CUSTODY INTACT	CUSTODY SEAL NO.	SL LOG NO.	LABORATORY REMARKS
L. Bond	6/26/91 10:10	YES NO		34317	RUSH

JUN-26-1991 15:29 FROM SAVANNAH LABS. SP.

SL SAVANNAH LABORATORIES AND ENVIRONMENTAL SERVICES, INC.
ANALYSIS REQUEST AND CHAIN OF CUSTODY RECORD

Savannah Division
5102 LaRoche Avenue
Savannah, GA 31404
Phone: (912) 354-7858

JOB NO.:
P.O. NO.:
PROJECT NAME: Industri-Plex Site
PAGE 2 OF 4
CLIENT NAME: Golder Associates Inc.
TELEPHONE: 609-273-1110
CLIENT ADDRESS: 20000 Horizon Way, #500, Mt Laurel, NJ 08054
CLIENT PROJECT MANAGER: Bob Glazier
STANDARD ☐
RUSH ☒
DATE REPORT REQUESTED 7/11/91

REQUIRED ANALYSES: As, Pb, Cr SW-846

SAMPLING DATE	SAMPLING TIME	SAMPLE ID	AQUEOUS MATRIX	NONAQUEOUS MATRIX	As, Pb, Cr SW-846									REMARKS
6-24-91		IP/SW-1/121/036/1/3/1		X	X									
↓		IP/SW-1/122/006/1/3/1		X	X									
		IP/SW-1/122/012/1/3/1		X	X									
		IP/SW-1/122/018/1/3/1		X	X									
		IP/SW-1/122/027/1/3/1		X	X									
		IP/SW-1/122/036/1/3/1		X	X									
		IP/SW-1/124/006/1/3/1		X	X									
		IP/SW-1/124/012/1/3/1		X	X									
↓		IP/SW-1/124/018/1/3/1		X	X									

RELINQUISHED BY: (SIGNATURE)	DATE/TIME	RECEIVED BY: (SIGNATURE)	DATE/TIME	RELINQUISHED BY: (SIGNATURE)	DATE/TIME
Robert M. Glazier	6-25-91 1430				
	DATE/TIME	RECEIVED BY: (SIGNATURE)	DATE/TIME	RELINQUISHED BY: (SIGNATURE)	DATE/TIME

LABORATORY USE ONLY Fed Ex Airbill No. 774 8886342

RECEIVED FOR LABORATORY BY: (SIGNATURE)	DATE/TIME	CUSTODY INTACT	CUSTODY SEAL NO.	SL LOG NO.	LABORATORY REMARKS
L. Bonds	6/26/91 10:10 am	YES NO (YES circled)		34317	RUSH

JUN-26-1991 15:26 FROM SAVANNAH LABS, GA. TO 916092732110 P.04

SL SAVANNAH LABORATORIES AND ENVIRONMENTAL SERVICES, INC.
ANALYSIS REQUEST AND CHAIN OF CUSTODY RECORD

Savannah Division
5102 LaRoche Avenue
Savannah, Ga. 31404
Phone: (912) 354-7858

JOB NO.: | P.O. NO.: | PROJECT NAME: Industri-Plex Site | PAGE 3 OF 4

CLIENT NAME: Golder Associates Inc | TELEPHONE: 609-273-1110

CLIENT ADDRESS: 20,000 Horizon Way #500, Mt Laurel, NJ 08054

CLIENT PROJECT MANAGER: Bob Glazier

STANDARD ☐ RUSH ☒

DATE REPORT REQUESTED: 7/11/91

REQUIRED ANALYSES: As, Pb, Cr SW-846

SAMPLING DATE	SAMPLING TIME	SAMPLE ID	AQUEOUS MATRIX	NONAQUEOUS MATRIX	As, Pb, Cr SW-846									REMARKS
6-24-91		IP/SW-1/124/027/1/3/1		X	X									
6-24-91		IP/SW-1/124/036/1/3/1		X	X									
6-24-91		IP/SW-1/EBA/000/2/3/1	X		X									equipment rinsate blank
6-24-91		IP/SW-1/121/006/1/d/1		X	X									field duplicate
6-24-91		IP/SW-1/120/036/1/M/1		X	X									MS
6-24-91		IP/SW-1/120/036/1/N/1		X	X									MSD
6-25-91		IP/SW-1/123/006/1/3/1		X	X									
6-25-91		IP/SW-1/123/012/1/3/1		X	X									
6-25-91		IP/SW-1/123/006/1/d/1		X	X									field duplicate

RELINQUISHED BY: (SIGNATURE)	DATE/TIME	RECEIVED BY: (SIGNATURE)	DATE/TIME	RELINQUISHED BY: (SIGNATURE)	DATE/TIME
Robert M. Glazier	6-25-91 1400				
	DATE/TIME	RECEIVED BY: (SIGNATURE)	DATE/TIME	RELINQUISHED BY: (SIGNATURE)	DATE/TIME

LABORATORY USE ONLY Fed. Ex Airbill No. 7748886342

RECEIVED FOR LABORATORY BY: (SIGNATURE)	DATE/TIME	CUSTODY INTACT	CUSTODY SEAL NO.	SL LOG NO.	LABORATORY REMARKS:
E. Bonds	6/26/91 1020	YES		34317	RUSH

TOTAL P.05

SL SAVANNAH LABORATORIES AND ENVIRONMENTAL SERVICES, INC.
ANALYSIS REQUEST AND CHAIN OF CUSTODY RECORD

Savannah Division
[illegible] Avenue
Savannah, GA. 31404
Phone: [illegible]

JOB NO.	P.O. NO.	PROJECT NAME	PAGE	OF
		Industri-Plex Site	4	4

CLIENT NAME	TELEPHONE
Golder Associates, Inc.	609-273-1110

CLIENT ADDRESS: 20,000 Horizon Way #500, Mt Laurel, NJ 08054

CLIENT PROJECT MANAGER: Bob Glazier

REQUIRED ANALYSES: As, Hg, Cr SW-846

STANDARD ☐ RUSH ☒

DATE REPORT REQUESTED: 7/11/91

SAMPLING DATE	SAMPLING TIME	SAMPLE ID	AQUEOUS MATRIX	NONAQUEOUS MATRIX	As, Hg, Cr SW-846									REMARKS
6-25-91		IP/SW-1/123/012/1/M/1		X	X									MS
6-25-91		IP/SW-1/123/012/1/N/1		X	X									MSD
6-25-91		IP/SW-1/EBB/000/2/3/1	X		X									equipment rinsate blank

RELINQUISHED BY: (SIGNATURE)	DATE/TIME	RECEIVED BY: (SIGNATURE)	DATE/TIME	RELINQUISHED BY: (SIGNATURE)	DATE/TIME
Robert M Glazier	6-25-91 1430				
	DATE/TIME	RECEIVED BY: (SIGNATURE)	DATE/TIME	RELINQUISHED BY: (SIGNATURE)	DATE/TIME

LABORATORY USE ONLY Fed. Ex. Airbill No. 7748886342

RECEIVED FOR LABORATORY BY: (SIGNATURE)	DATE/TIME	CUSTODY INTACT	CUSTODY SEAL NO.	SL LOG NO.	LABORATORY REMARKS:
L. Bonds	6/26/91 1000 am	YES NO		34317	RUSH

ATTACHMENT D

Laboratory Report

SL SAVANNAH LABORATORIES
& ENVIRONMENTAL SERVICES, INC.

5102 LaRoche Avenue • Savannah, GA 31404 • (912) 354-7858 • Fax (912) 352-0165

LOG NO: S1-34317

Received: 26 JUN 91

Ms. Elizabeth Auda
Golder Associates, Inc.
20000 Horizon Way, Suite 500
Mt. Laurel, NJ 08054

Project: Industri-Plex Site
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , SOLID OR SEMISOLID SAMPLES	DATE SAMPLED
34317-1	IP/SW-1/121/036/1/3/1 (06.24.91)	06-24-91
34317-2	IP/SW-1/122/006/1/3/1 (06.24.91)	06-24-91
34317-3	IP/SW-1/122/012/1/3/1 (06.24.91)	06-24-91
34317-4	IP/SW-1/122/018/1/3/1 (06.24.91)	06-24-91
34317-5	IP/SW-1/122/027/1/3/1 (06.24.91)	06-24-91

PARAMETER	34317-1	34317-2	34317-3	34317-4	34317-5
Arsenic, mg/kg dw	<13	<56	<48	<26	<16
Lead, mg/kg dw	<6.7	310	38	17	<8.2
Chromium, mg/kg dw	4.7	37	11	55	5.6
Percent Solids, %	75	18	21	39	61

SAVANNAH LABORATORIES
& ENVIRONMENTAL SERVICES, INC.

5102 LaRoche Avenue • Savannah, GA 31404 • (912) 354-7858 • Fax (912) 352-0165

LOG NO: S1-34317

Received: 26 JUN 91

Ms. Elizabeth Auda
Golder Associates, Inc.
20000 Horizon Way, Suite 500
Mt. Laurel, NJ 08054

Project: Industri-Plex Site
Sampled By: Client

REPORT OF RESULTS

Page 2

LOG NO	SAMPLE DESCRIPTION , SOLID OR SEMISOLID SAMPLES	DATE SAMPLED
34317-6	IP/SW-1/122/036/1/3/1 (06.24.91)	06-24-91
34317-7	IP/SW-1/124/006/1/3/1 (06.24.91)	06-24-91
34317-8	IP/SW-1/124/012/1/3/1 (06.24.91)	06-24-91
34317-9	IP/SW-1/124/018/1/3/1 (06.24.91)	06-24-91
34317-10	IP/SW-1/120/006/1/3/1 (06.24.91)	06-24-91

PARAMETER	34317-6	34317-7	34317-8	34317-9	34317-10
Arsenic, mg/kg dw	<16	<43	<19	<14	<16
Lead, mg/kg dw	<8.1	86	12	<6.8	52
Chromium, mg/kg dw	5.7	24	19	8.9	1.7
Percent Solids, %	62	23	52	74	61

SL SAVANNAH LABORATORIES
& ENVIRONMENTAL SERVICES, INC.

5102 LaRoche Avenue • Savannah, GA 31404 • (912) 354-7858 • Fax (912) 352-0165

LOG NO: 81-34317

Received: 26 JUN 91

Ms. Elizabeth Auda
Golder Associates, Inc.
20000 Horizon Way, Suite 500
Mt. Laurel, NJ 08054

Project: Industri-Plex Site
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , SOLID OR SEMISOLID SAMPLES	DATE SAMPLED
34317-11	IP/SW-1/120/012/1/3/1 (06.24.91)	06-24-91
34317-12	IP/SW-1/120/018/1/3/1 (06.24.91)	06-24-91
34317-13	IP/SW-1/120/027/1/3/1 (06.24.91)	06-24-91
34317-14	IP/SW-1/120/036/1/3/1 (06.24.91)	06-24-91
34317-15	IP/SW-1/121/006/1/3/1 (06.24.91)	06-24-91

PARAMETER	34317-11	34317-12	34317-13	34317-14	34317-15
Arsenic, mg/kg dw	<14	<14	<13	<12	<37
Lead, mg/kg dw	12	<6.9	<6.6	<6.2	470
Chromium, mg/kg dw	3.1	6.2	6.2	5.0	37
Percent Solids, %	73	72	76	81	27

SAVANNAH LABORATORIES
& ENVIRONMENTAL SERVICES, INC.

5102 LaRoche Avenue • Savannah, GA 31404 • (912) 354-7858 • Fax (912) 352-0165

LOG NO: S1-34317

Received: 26 JUN 91

Ms. Elizabeth Auda
Golder Associates, Inc.
20000 Horizon Way, Suite 500
Mt. Laurel, NJ 08054

Project: Industri-Plex Site
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , SOLID OR SEMISOLID SAMPLES	DATE SAMPLED
34317-16	IP/SW-1/121/012/1/3/1 (06.24.91)	06-24-91
34317-17	IP/SW-1/121/018/1/3/1 (06.24.91)	06-24-91
34317-18	IP/SW-1/121/027/1/3/1 (06.24.91)	06-24-91
34317-19	IP/SW-1/124/027/1/3/1 (06.24.91)	06-24-91
34317-20	IP/SW-1/124/036/1/3/1 (06.24.91)	06-24-91

PARAMETER	34317-16	34317-17	34317-18	34317-19	34317-20
Arsenic, mg/kg dw	<13	<13	<12	<14	<13
Lead, mg/kg dw	<6.6	<6.3	<6.1	<6.8	<6.4
Chromium, mg/kg dw	5.8	5.4	5.5	6.7	7.3
Percent Solids, %	76	79	82	73	78

SL SAVANNAH LABORATORIES
& ENVIRONMENTAL SERVICES, INC.

5102 LaRoche Avenue • Savannah, GA 31404 • (912) 354-7858 • Fax (912) 352-0165

LOG NO: 81-34317

Received: 26 JUN 91

Ms. Elizabeth Auda
Golder Associates, Inc.
20000 Horizon Way, Suite 500
Mt. Laurel, NJ 08054

Project: Industri-Plex Site
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , SOLID OR SEMISOLID SAMPLES	DATE SAMPLED
34317-21	IP/SW-1/121/006/1/D/1 (06.24.91)	06-24-91
34317-22	IP/SW-1/120/036/1/M/1 (06.24.91)	06-24-91
34317-23	IP/SW-1/120/036/1/N/1 (06.24.91)	06-24-91
34317-24	IP/SW-1/123/006/1/3/1 (06.25.91)	06-25-91
34317-25	IP/SW-1/123/012/1/3/1 (06.25.91)	06-25-91

PARAMETER	34317-21	34317-22	34317-23	34317-24	34317-25
Arsenic, mg/kg dw	<33	116	124	<45	<24
Lead, mg/kg dw	480	128	135	310	23
Chromium, mg/kg dw	38	128	134	27	8.7
Percent Solids, %	30	82	80	22	42

SAVANNAH LABORATORIES
& ENVIRONMENTAL SERVICES, INC.

5102 LaRoche Avenue • Savannah, GA 31404 • (912) 354-7858 • Fax (912) 352-0165

LOG NO: S1-34317

Received: 26 JUN 91

Ms. Elizabeth Auda
Golder Associates, Inc.
20000 Horizon Way, Suite 500
Mt. Laurel, NJ 08054

Project: Industri-Plex Site
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , SOLID OR SEMISOLID SAMPLES	DATE SAMPLED
34317-26	IP/SW-1/123/006/1/D/1 (06.25.91)	06-25-91
34317-27	IP/SW-1/123/012/1/M/1 (06.25.91)	06-25-91
34317-28	IP/SW-1/123/012/1/N/1 (06.25.91)	06-25-91

PARAMETER	34317-26	34317-27	34317-28
Arsenic, mg/kg dw	<45	207	192
Lead, mg/kg dw	300	242	225
Chromium, mg/kg dw	25	211	195
Percent Solids, %	22	47	51

SAVANNAH LABORATORIES
& ENVIRONMENTAL SERVICES, INC.

5102 LaRoche Avenue • Savannah, GA 31404 • (912) 354-7858 • Fax (912) 352-0165

LOG NO: 81-34317

Received: 26 JUN 91

Ms. Elizabeth Auda
Golder Associates, Inc.
20000 Horizon Way, Suite 500
Mt. Laurel, NJ 08054

Project: Industri-Plex Site
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR SOLID/SEMISOLID
34317-29	Method Blank-Soil
34317-30	MS/MSD % Recovery (IP/SW-1/120/036/1/M-N/1)
34317-31	% RPD (IP/SW-1/120/036/1/M-N/1)
34317-32	MS/MSD % Recovery (IP/SW-1/123/012/1/M-N/1)
34317-33	% RPD (IP/SW-1/123/012/1/M-N/1)

PARAMETER	34317-29	34317-30	34317-31	34317-32	34317-33
Arsenic, mg/kg dw	<10	95/99 %	4.1 %	97/98 %	1.0 %
Lead, mg/kg dw	<5.0	105/108 %	2.8 %	103/103 %	0 %
Chromium, mg/kg dw	<1.0	100/102 %	2.0 %	94/94 %	0 %

MS Expected Value (S134317-22) Arsenic,Lead = 122
Chromium = 123 (mg/kg dw).
MSD Expected Value (S134317-23) Arsenic,Lead = 125
Chromium = 126 (mg/kg dw).
MS Expected Value (S134317-27) Arsenic,Lead = 213
Chromium = 215 (mg/kg dw).
MSD Expected Value (S134317-28) Arsenic,Lead = 196
Chromium = 198 (mg/kg dw).

SL SAVANNAH LABORATORIES
& ENVIRONMENTAL SERVICES, INC.

5102 LaRoche Avenue • Savannah, GA 31404 • (912) 354-7858 • Fax (912) 352-0165

LOG NO: S1-34317

Received: 26 JUN 91

Ms. Elizabeth Auda
Golder Associates, Inc.
20000 Horizon Way, Suite 500
Mt. Laurel, NJ 08054

Project: Industri-Plex Site
Sampled By: Client

REPORT OF RESULTS

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LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR SOLID/SEMISOLID
34317-34	Date Analysed

PARAMETER	34317-34
Arsenic, mg/kg dw	07.09.91
Lead, mg/kg dw	07.01.91
Chromium, mg/kg dw	07.01.91

MS Expected Value (S134317-22) Arsenic,Lead = 122
Chromium = 123 (mg/kg dw).
MSD Expected Value (S134317-23) Arsenic,Lead = 125
Chromium = 126 (mg/kg dw).
MS Expected Value (S134317-27) Arsenic,Lead = 213
Chromium = 215 (mg/kg dw).
MSD Expected Value (S134317-28) Arsenic,Lead = 196
Chromium = 198 (mg/kg dw).

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5102 LaRoche Avenue • Savannah, GA 31404 • (912) 354-7858 • Fax (912) 352-0165

LOG NO: S1-34317

Received: 26 JUN 91

Ms. Elizabeth Auda
Golder Associates, Inc.
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Project: Industri-Plex Site
Sampled By: Client

REPORT OF RESULTS

LOG NO	SAMPLE DESCRIPTION , LIQUID SAMPLES	DATE SAMPLED
34317-35	IP/SW-1/EBA/000/2/3/1 (06.24.91)	06-24-91
34317-36	IP/SW-1/EBB/000/2/3/1 (06.25.91)	06-25-91

PARAMETER	34317-35	34317-36
Arsenic, mg/l	<0.10	<0.10
Lead, mg/l	<0.050	<0.050
Chromium, mg/l	<0.010	<0.010

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LOG NO: S1-34317

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Project: Industri-Plex Site
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REPORT OF RESULTS

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LOG NO	SAMPLE DESCRIPTION , QC REPORT FOR LIQUID SAMPLES
34317-37	Method Blank-Water
34317-38	Lab Spike/Duplicate % Recovery
34317-39	% RPD
34317-40	Date Analysed

PARAMETER	34317-37	34317-38	34317-39	34317-40
Arsenic, mg/l	<0.10	110/109 %	0.91 %	07.02.91
Lead, mg/l	<0.050	105/105 %	0 %	07.02.91
Chromium, mg/l	<0.010	103/102 %	0.98 %	07.02.91

Methods: EPA SW-846.

William D. Sherrod

William D. Sherrod

ATTACHMENT E

Data Quality Assessment

Lab Log No. S1-34317

INDUSTRI-PLEX PRE-DESIGN INVESTIGATION

ASSESSMENT OF OVERALL DATA QUALITY
FOR TASK SW-1/Phase 2

PERFORMED BY: Bob Glazier DATE: 7/15/91

YES/NO/NA

1. Were the QAPjP, laboratory reports, and field documentation available to support data assessment procedures? Yes

2. Precision:

Are DCS RPD within control limits? Yes
Are lab duplicate RPD within control limits? Yes
Are field duplicate RPD within control limits? Yes
Are MS/MSD RPD within control limits? Yes
Overall assessment of precision The data are of sufficient precision for use in Remedial Design.

3. Accuracy:

Is absolute recovery within control limits for DCS? Yes
Is relative recovery within control limits for MS/MSD? Yes
Overall assessment of accuracy The data are of sufficient accuracy for use in Remedial Design.

4. Representativeness:

Were procedures in the FSP followed? Yes
If not, were procedural variations approved and documented? N/A
Were sample preservation procedures given in the FSP followed? Yes
Were data reported in the proper units? Yes
Was blank contamination not evident or well documented at low levels? Yes
Were field duplicates within control limits? Yes
Overall assessment of representativeness The data are representative of site conditions.

INDUSTRI-PLEX PRE-DESIGN INVESTIGATION

ASSESSMENT OF OVERALL DATA QUALITY
FOR TASK SW-1/Phase 2

(continued)

YES/NO/NA

5. Comparability:

Are data traceable to a standard method? Yes

Are methods approved/accepted as giving valid results? Yes

Are data reported in proper units? Yes

Overall assessment of comparability

The data are comparable to other data collected in the RI/FS and Pre-Design Investigation.

6. Completeness:

Is the fraction of valid data within control limits? Yes

If not, are the data sufficient to meet the task objectives? N/A

Are critical (background) samples sufficient and valid? N/A

Overall assessment of completeness

The data set is complete.

7. Are the data useable and consistent with the objectives of the study? Yes

8. Comments: N/A

C:6255:ODQFORM

Lab Log No. 51-34317

INDUSTRI-PLEX PRE-DESIGN INVESTIGATION

ASSESSMENT OF FIELD PERFORMANCE
FOR TASK SW-1/Phase 2

SAMPLER/ORGANIZATION: David S. Ley/Golder Associates REPORT # 51-34317

VALIDATED BY: Bob Glazier DATE: 7/16/91

	YES/NO/NA
1. Does field documentation include:	
date/time samples collected?	yes
sample location?	yes
name of sampler?	yes
field measurements?	N/A
sampling method?	yes
instruments/methods for field measurements?	N/A
calibration/maintenance of field instruments?	N/A
sampling containers used (COC*)?	yes
sample preservation procedures (see COC*)?	yes
Chain-of-Custody procedures?	yes
field quality control procedures?	yes
2. Were procedures in the Field Sampling Plan followed?	yes
If not, were procedural variances approved and documented?	N/A
3. Was contamination of field blank samples not evident, or well documented at low levels?	yes
4. Are field duplicates within control limits?	yes

5. Comments: N/A

* Chain-of-Custody Form

C:6255:FPFORM

Lab Log No. S1-34317

INDUSTRI-PLEX PRE-DESIGN INVESTIGATION

ASSESSMENT OF LABORATORY PERFORMANCE
FOR TASK Sw-1/Phase 2

LABORATORY: Savannah Labs REPORT # S1-34317

VALIDATED BY: Bob Glazier DATE: 7/16/91

	YES/NO/NA
1. Release authorization with signature present?	yes
2. Sample identification summary/description present?	yes
3. Analytical results present, including:	
correct units?	yes
detection limits?	yes
method used?	yes
date sampled?	yes
date received?	yes
date prepared?	N/A
date analyzed?	yes ~~AO~~
dilutions noted?	N/A
4. Holding times met?	yes
5. Lab duplicate RPDs within control limits (35%)?	yes
Field duplicate RPDs within control limits (50%)?	yes
6. MS/MSD % recoveries within control limits (75-125%)?	yes
7. MS/MSD RPDs within control limits (50%)?	yes
8. Duplicate control sample (DCS) accuracy within given control limits (80-120%)?	yes
9. DCS precision within given control limits (20%)?	yes
10. Method blanks "clean"?	yes
11. Chain-of-Custody present and complete with signatures and dates?	yes
12. Name of analyst/supervisor given?	yes
13. Procedural deviations noted?	N/A
14. QC procedures given?	yes

Lab Log No. 51-34317

INDUSTRI-PLEX PRE-DESIGN INVESTIGATION

ASSESSMENT OF LABORATORY PERFORMANCE
FOR TASK SW-1/ Phase 2

(continued)

Note any violations to the assessment criteria listed above:

N/A

C:6255:ALP1FORM